IPPW SHORT COURSE

The process :
We got selected, now we have to build it, show it works!

Discovery and Surprise - Expected and Unexpected Science from Planetary Probes

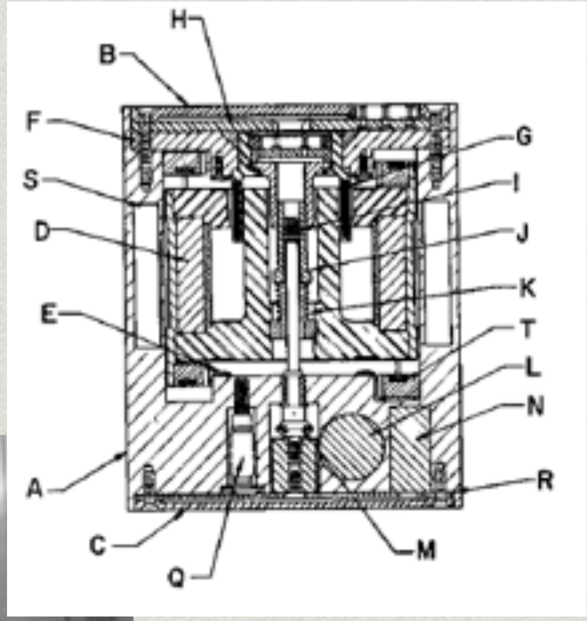
David Mimoun, ISAE Associate Professor, SEIS Project Scientist

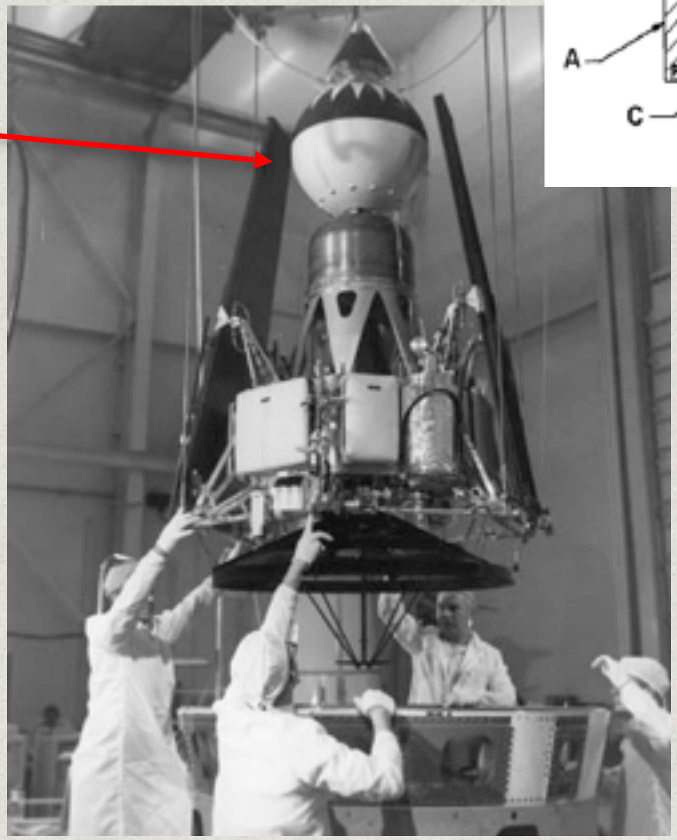
Contributions from Ph. Lognonné (IPGP), B. Banerdt (JPL), M. Golombek(JPL)

JUNE 15, 2014

Historical Context

- At the dawn of the age of planetary exploration, seismology was considered a key technique for understanding a planet.
  - The first instruments sent to the surface of another planet were seismometers.
    - Rangers 3-5, 1962
  - The two highest scientific priorities of the Apollo program were sample return and seismology.
    - Apollos 11,12,14,15,16, 1969-1977
  - The first landers on Mars carried seismometers.
    - Viking 1,2 ; 1975-1977
      - 19 months of operations
      - 10^-6 m/s^2/√Hz sensitivity
      - 1 failed, one measured the wind





NASA

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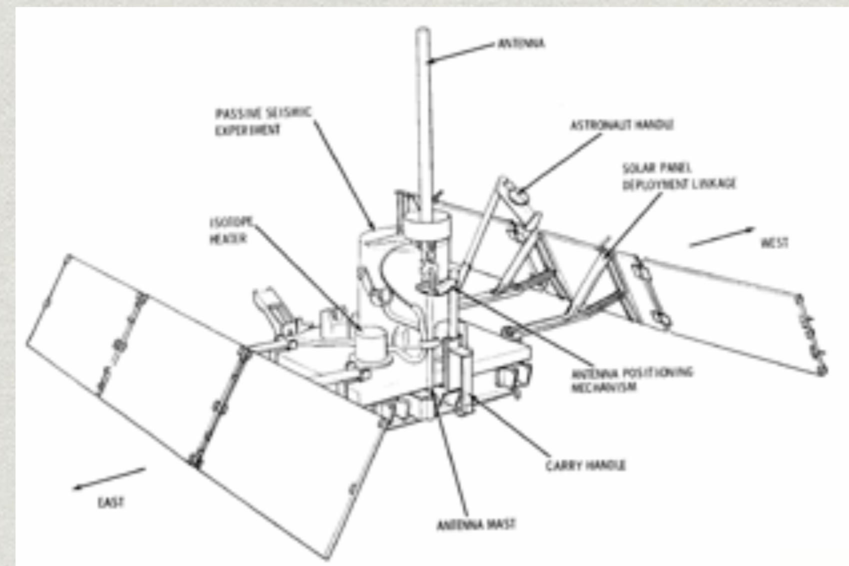
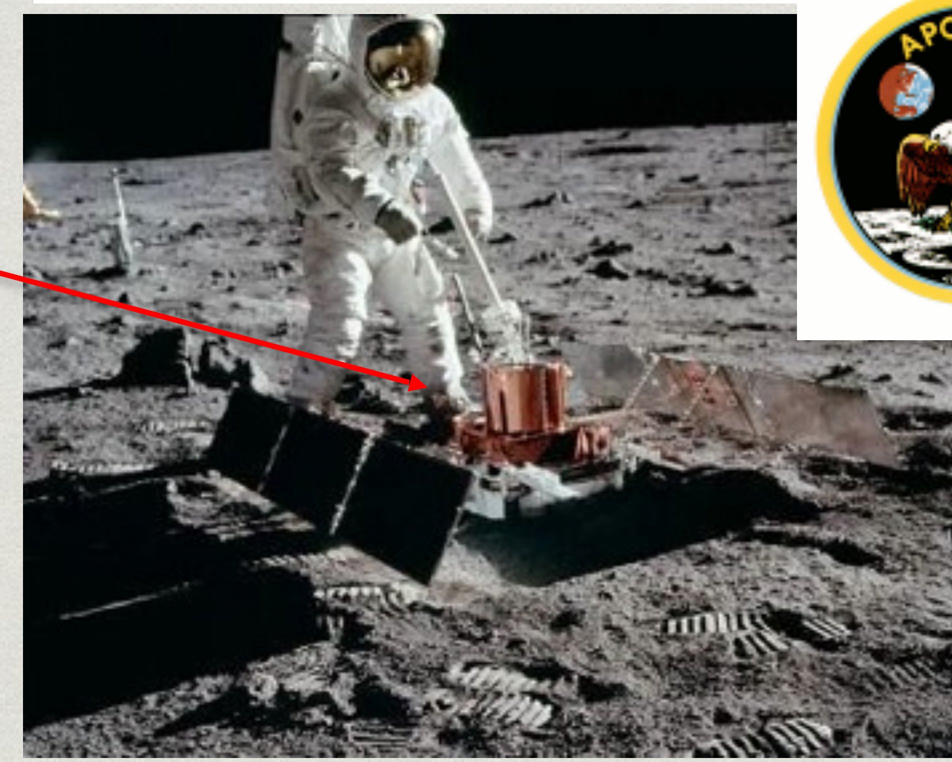


NASA



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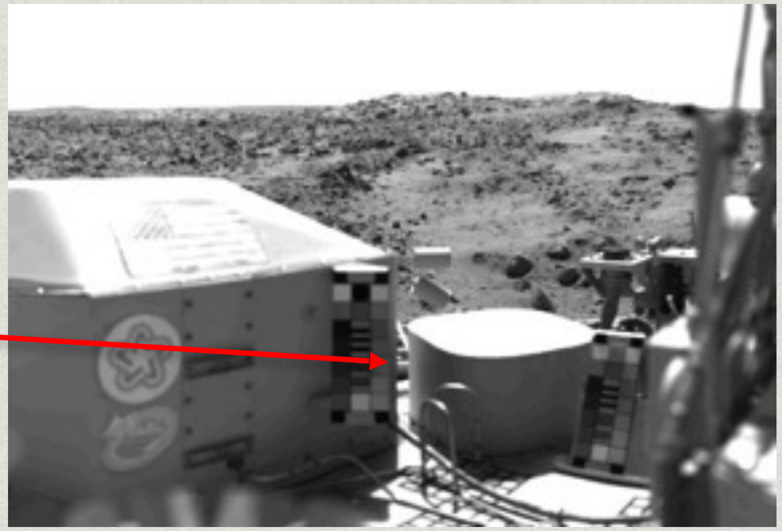
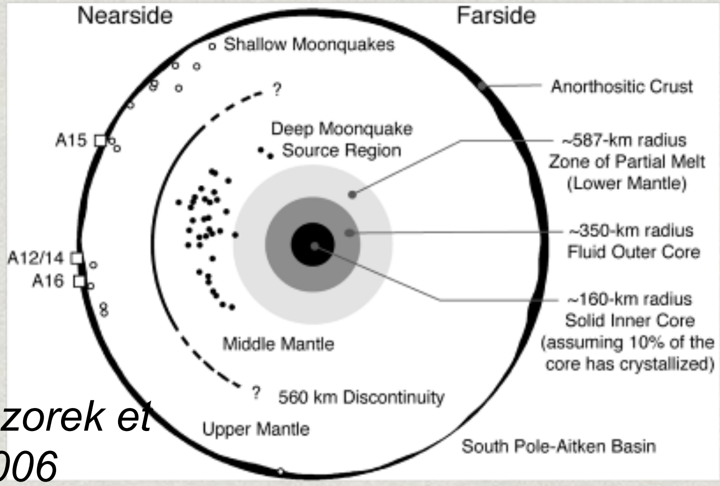


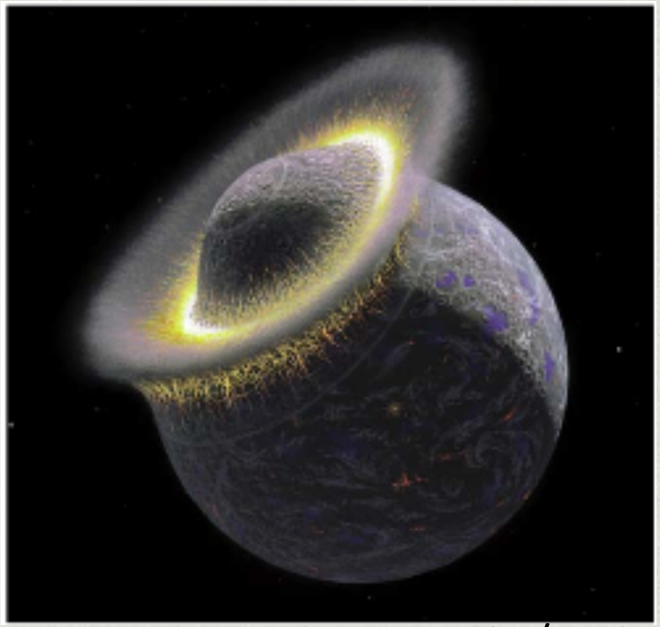
NASA

Why planetary seismology ?

Apollo heritage

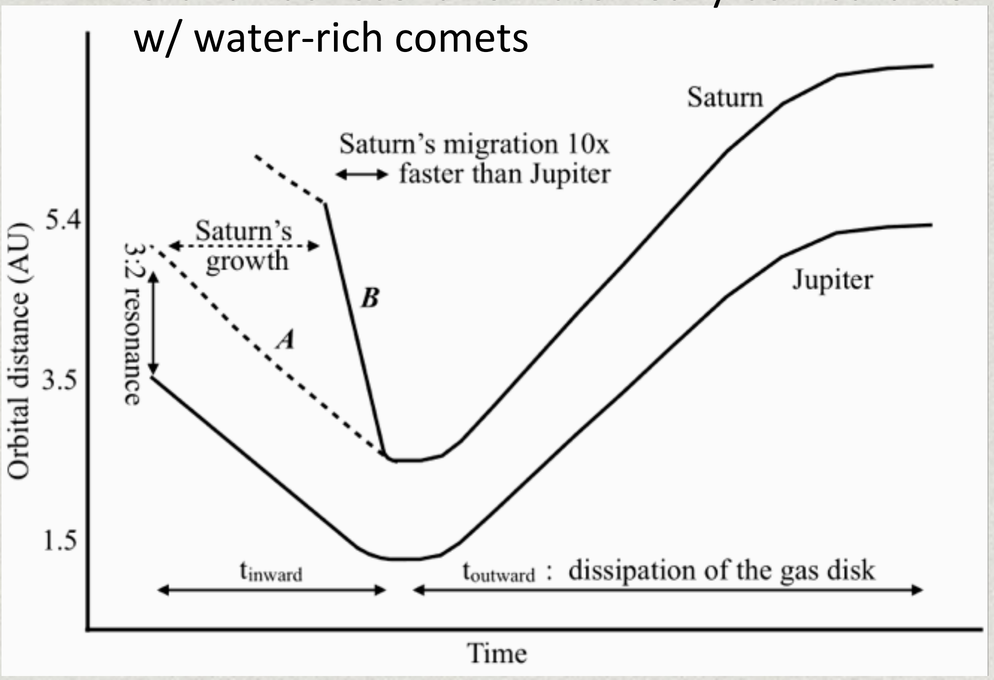


Wieczorek et al. 2006

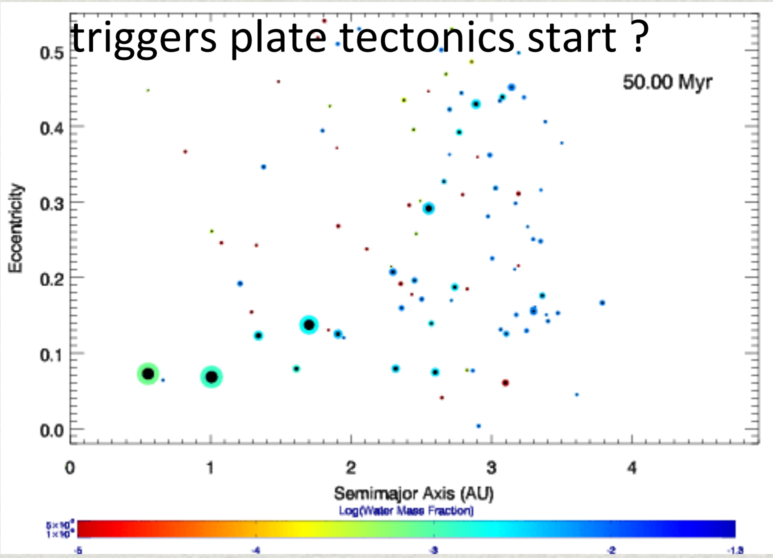


NASA/NRC

Grand Tack scenario : late heavy bombardment – w/ water-rich comets



Water abundance initial conditions triggers plate tectonics start ?

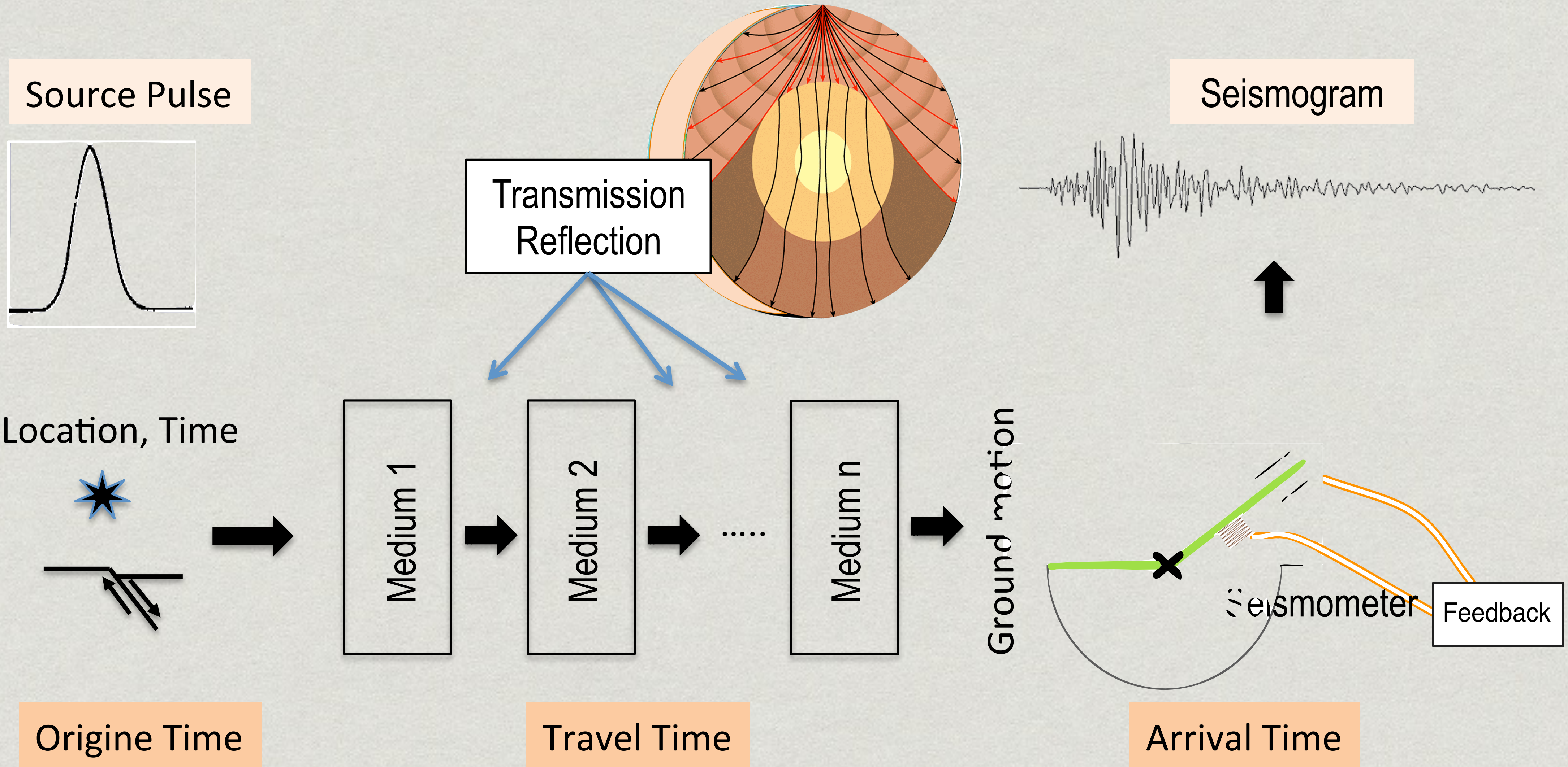


(S Raymond, K. Walsh)

Planetary Seismology tells the story of the solar system

Seismology basics

- Seismology use the transmission of waves through various materials to derive the structure of the medium seen along the path

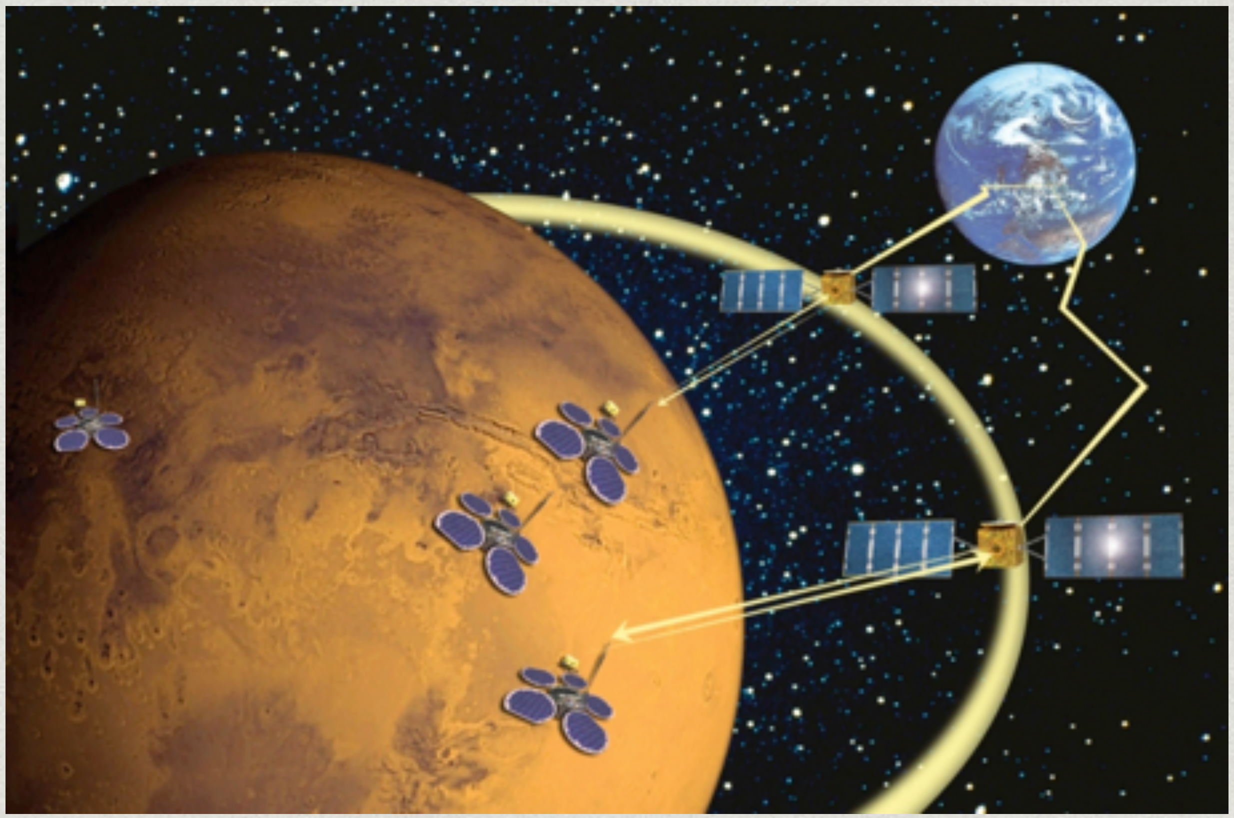


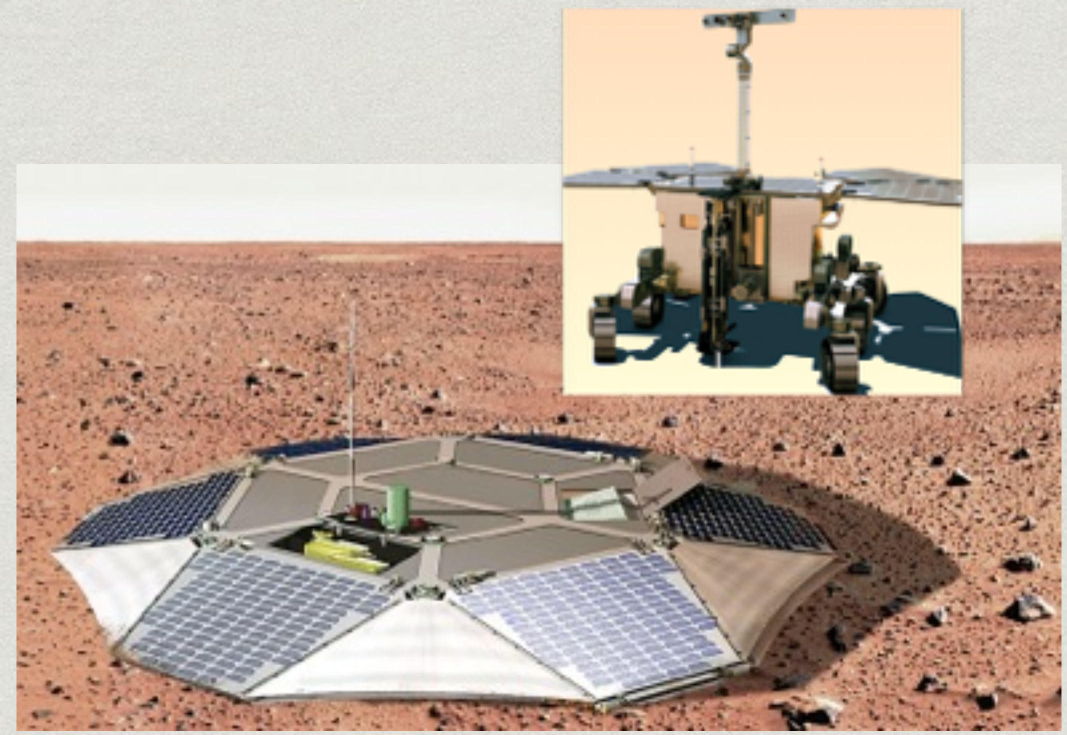
Modified after Schearer, 2010

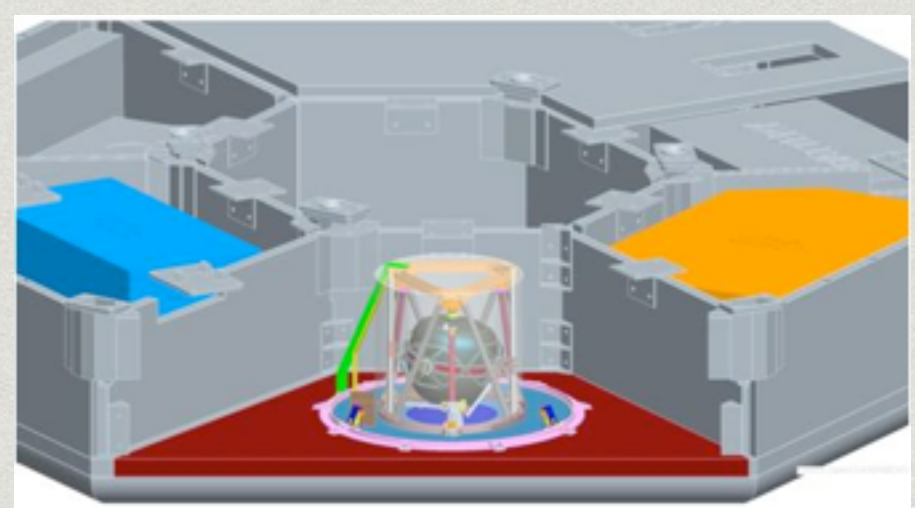
What is a seismometer ?

- A seismometer is just a (very) long period, very, very sensitive accelerometer which measures the ground motion…It is most of the time based on analog measurements : no « cool factor » …(e.g no laser shooting, no 3D image)
- However ..
    - Visible IR Imagers , Spectrometers : first microns
    - Neutrons : up to a meter
    - GPR : meters to km (best cases)
    - Seismometers : sounding down to the planet core
- Seismology with several stations (e.g Apollo, Netlander) : sounding with “classical” ray inversion
- Seismology with one station (like Insight)

Historical Context : Most recent efforts



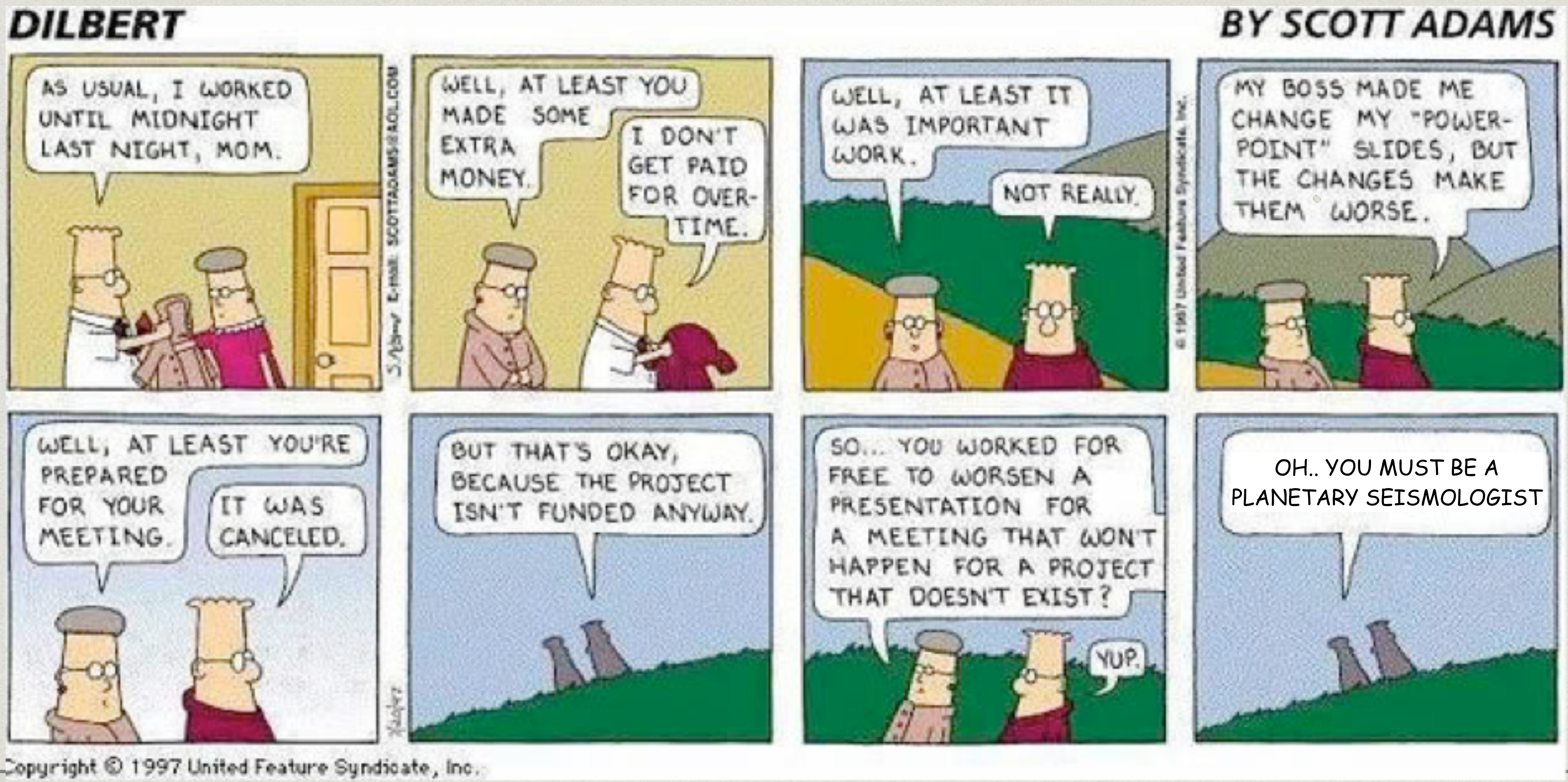




CREDITS CNES, ESA

Historical Context

- Since Viking, despite continuous efforts, no geophysical mission has made its way to Mars



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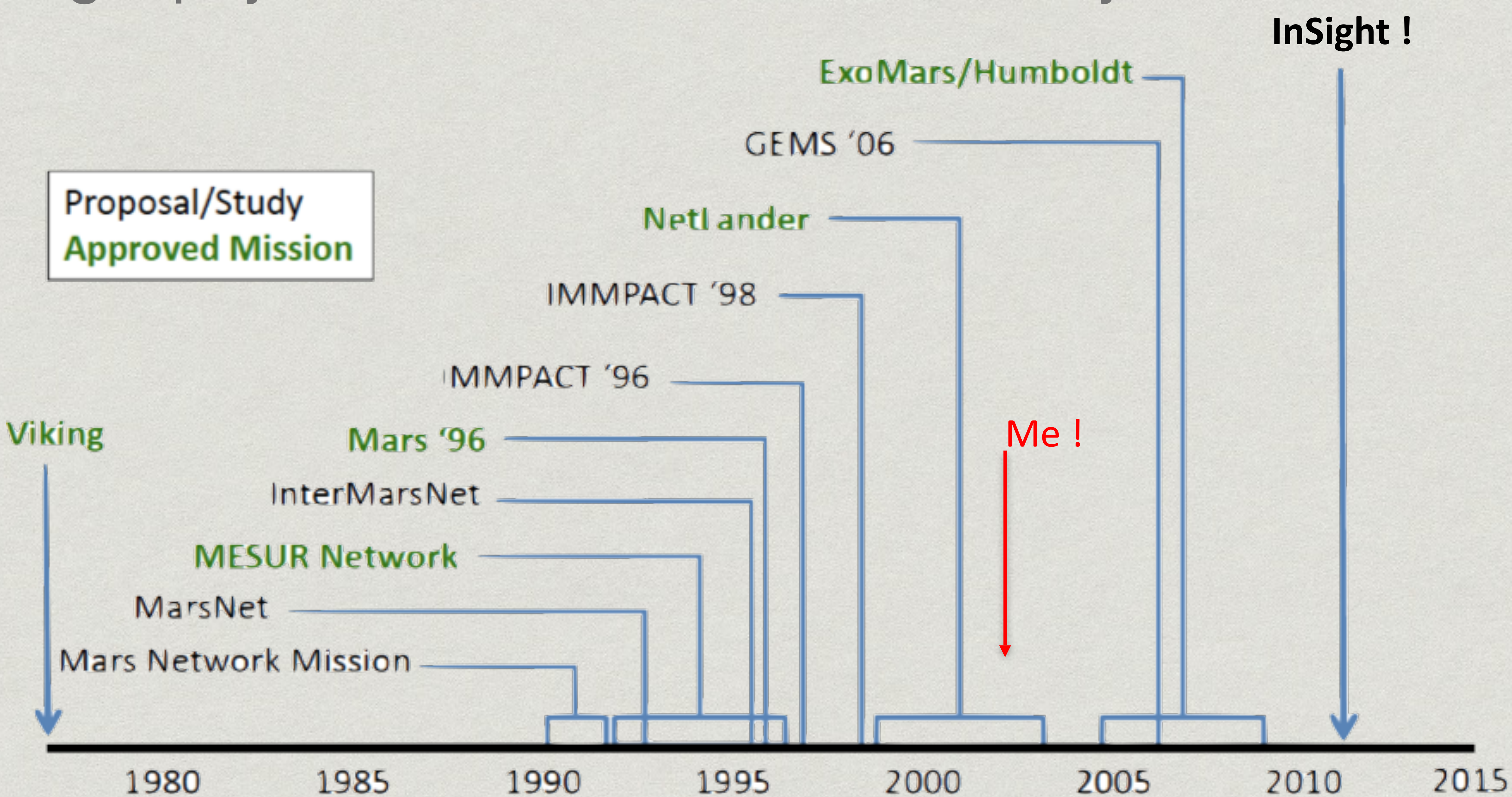
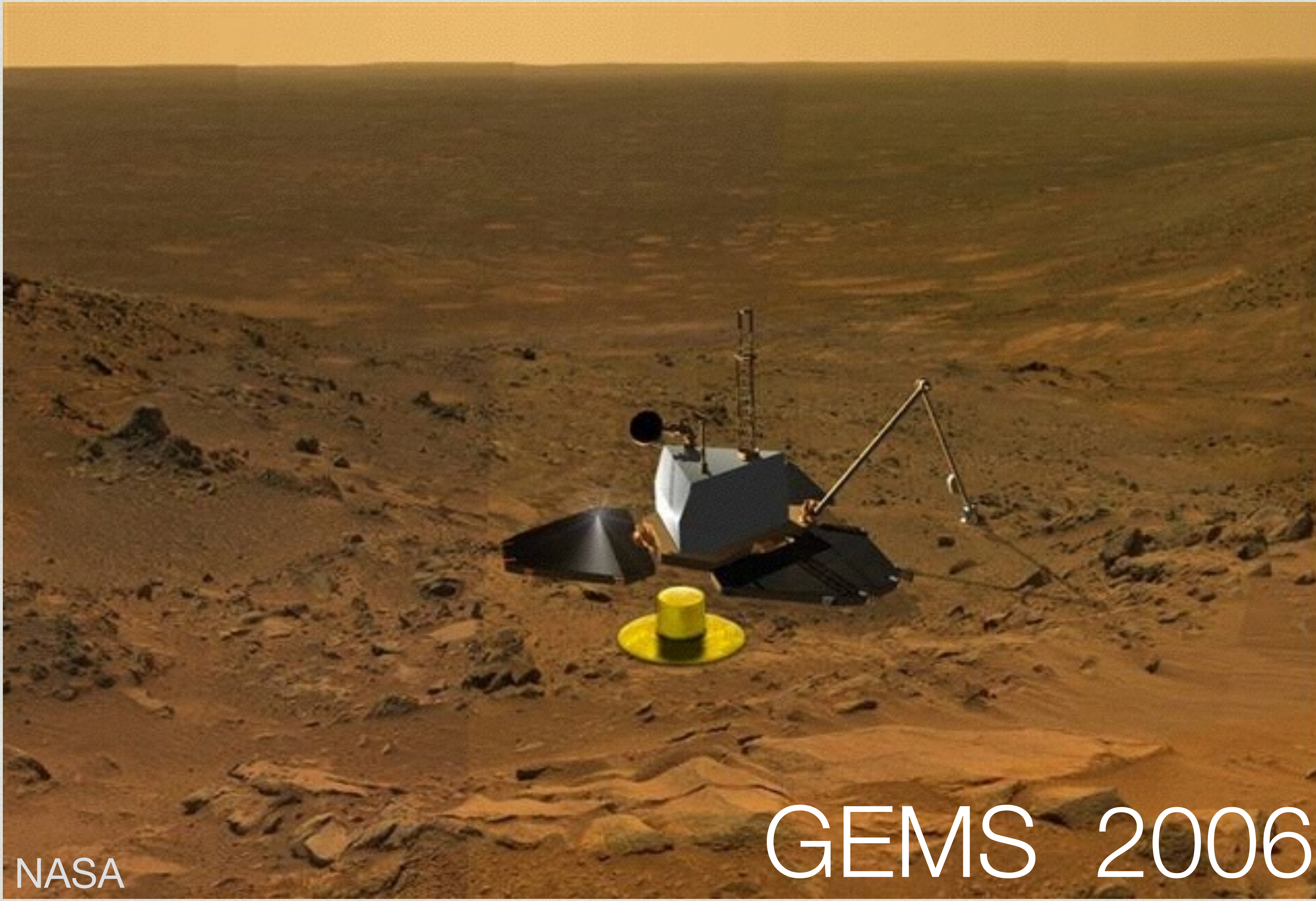


From GEMS(06) to Insight

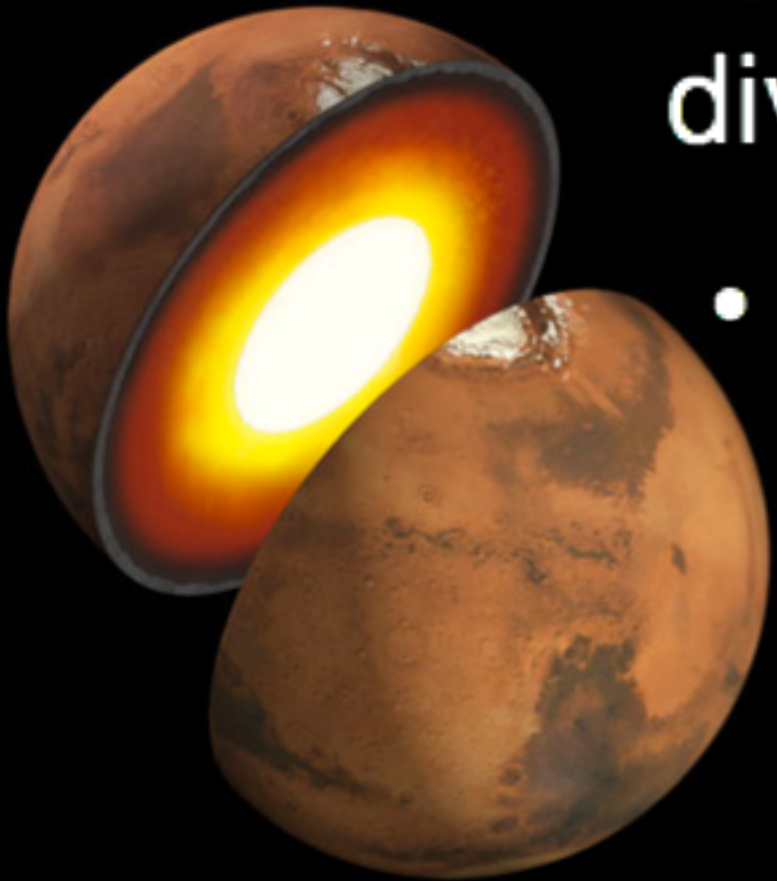


From GEMS(06) to Insight

- 2010 Discovery Proposal
- PI : W.B.Banerdt
- June 2011 Step 1 selection
- August 2012 Step 2 selection

Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars.

Directly Addresses NASA SMD and 2011 Decadal Survey Objectives:



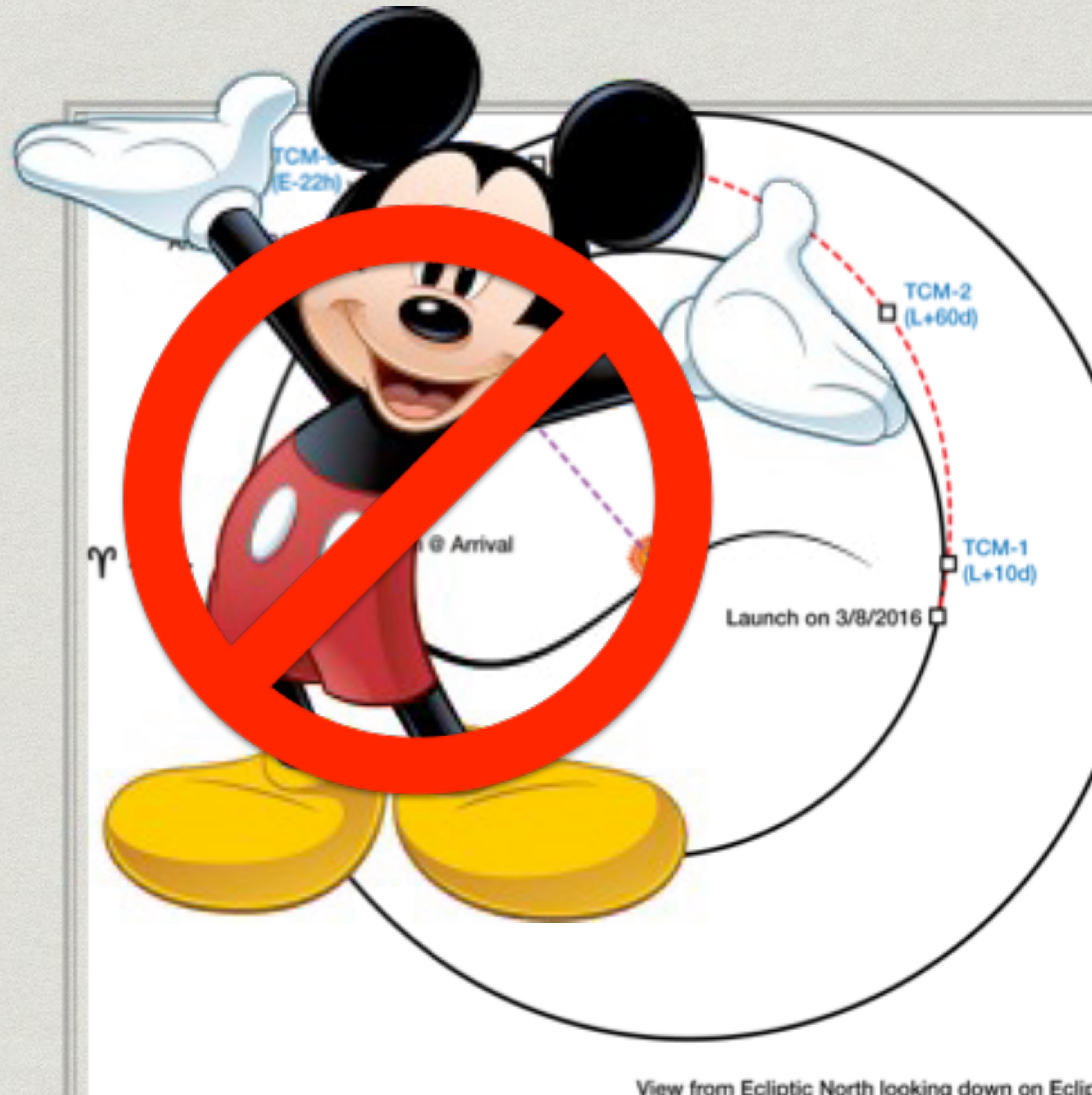
- "Understand the origin and diversity of terrestrial planets."
- "Understand how the evolution of terrestrial planets enables and limits the origin and evolution of life."

InSight Mission

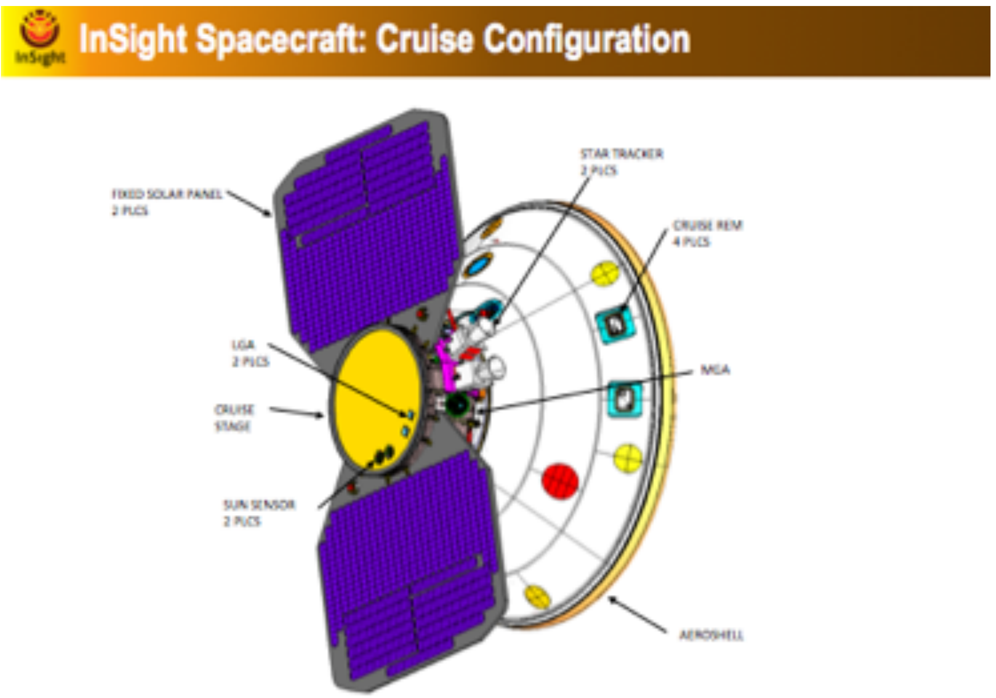
- InSight will fly a near-copy of the successful Phoenix lander
- Launch: March 4-24, 2016 from

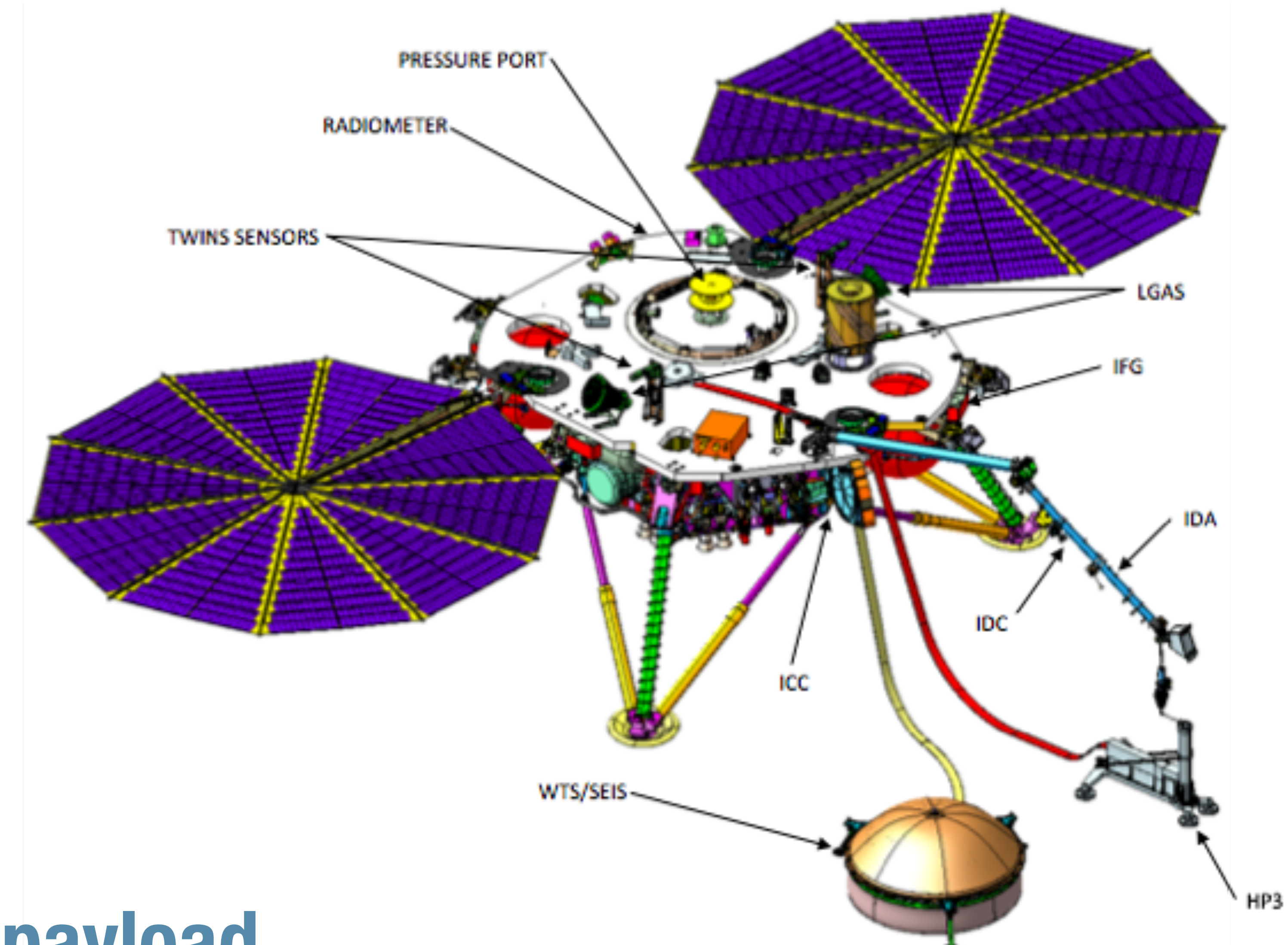
VANDENBERG

- Nominal end-of-mission: October 6, 2018



Spacecraft configuration

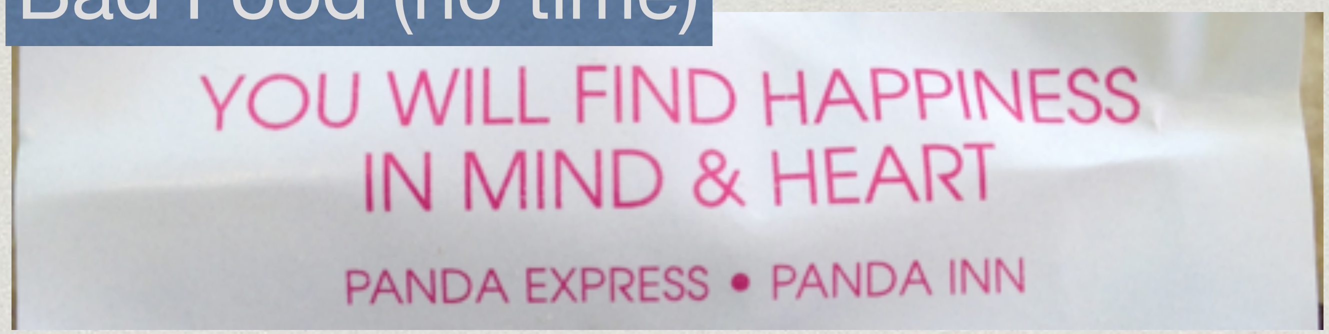




3 instruments : a focused payload

THE DAY BEFORE : THE SITE VISIT : HARD WORK

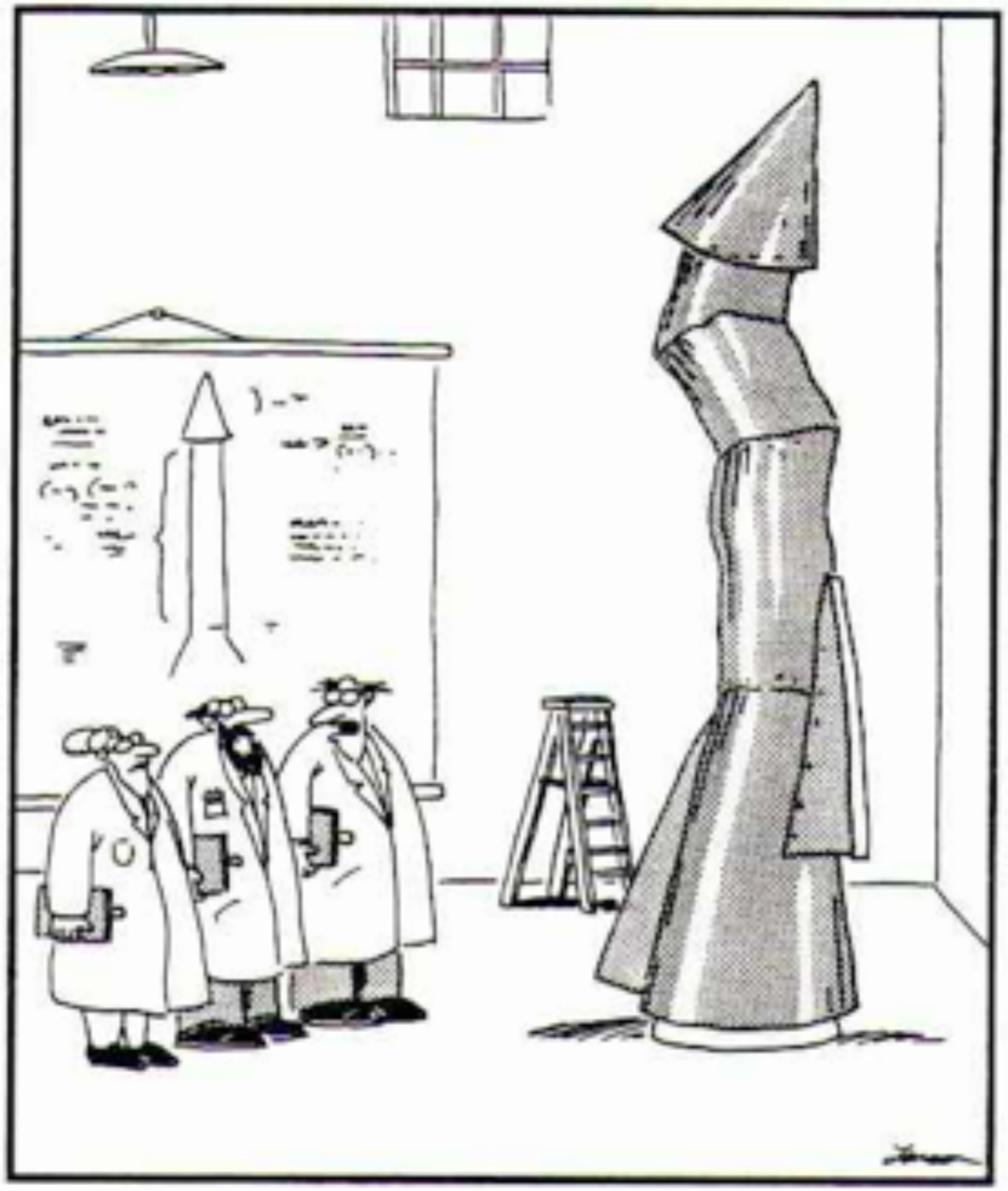
Bad Food (no time)



Rehersal …
Rehersal …
Rehersal …

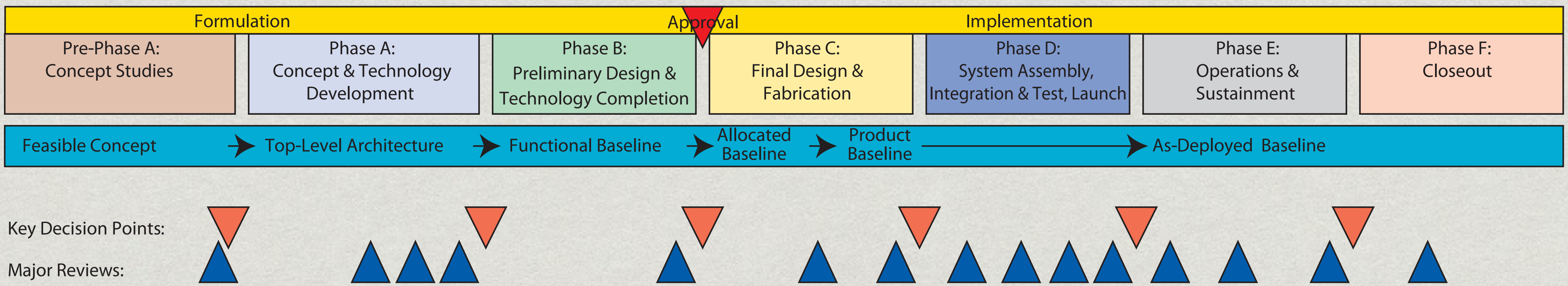
No pressure ….

The day after ….



"It's time we face reality, my friends. … We're not exactly rocket scientists."

The Day after selection : even more work



Step 1

Step 2

Development

PDR

CDR

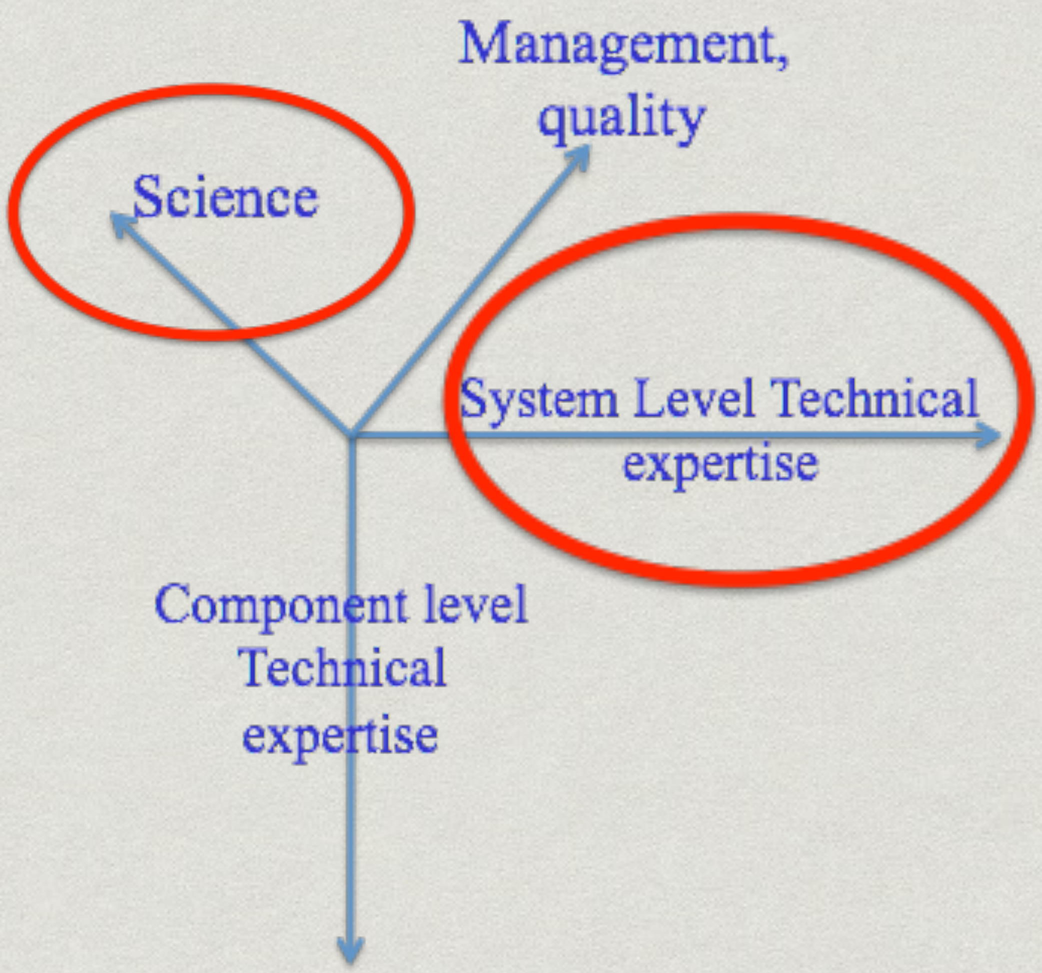
ATLO

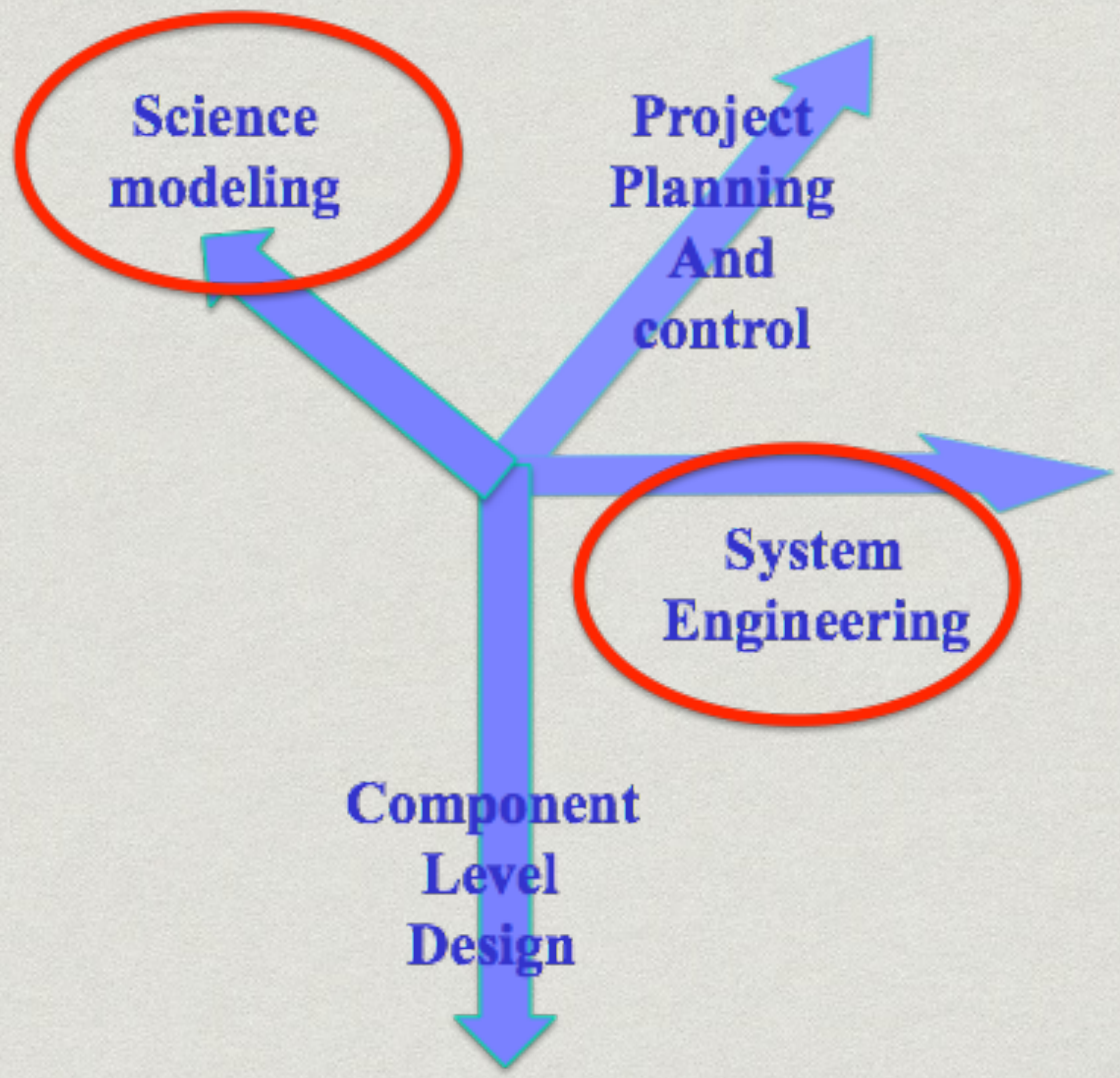
	Phase	Purpose	Typical Output
Formulation	Pre-Phase A Concept Studies	To produce a broad spectrum of ideas and alternatives for missions from which new programs/projects can be selected. Determine feasibility of desired system, develop mission concepts, draft system-level requirements, identify potential technology needs.	Feasible system concepts in the form of simulations, analysis, study reports, models, and mockups
	Phase A Concept and Technology Development	To determine the feasibility and desirability of a suggested new major system and establish an initial baseline compatibility with NASA's strategic plans. Develop final mission concept, system-level requirements, and needed system structure technology developments.	System concept definition in the form of simulations, analysis, engineering models, and mockups and trade study definition
Implementation	Phase B Preliminary Design and Technology Completion	To define the project in enough detail to establish an initial baseline capable of meeting mission needs. Develop system structure end product (and enabling product) requirements and generate a preliminary design for each system structure end product.	End products in the form of mockups, trade study results, specification and interface documents, and prototypes
	Phase C Final Design and Fabrication	To complete the detailed design of the system (and its associated subsystems, including its operations systems), fabricate hardware, and code software. Generate final designs for each system structure end product.	End product detailed designs, end product component fabrication, and software development
	Phase D System Assembly, Integration and Test, Launch	To assemble and integrate the products to create the system, meanwhile developing confidence that it will be able to meet the system requirements. Launch and prepare for operations. Perform system end product implementation, assembly, integration and test, and transition to use.	Operations-ready system end product with supporting related enabling products
	Phase E Operations and Sustainment	To conduct the mission and meet the initially identified need and maintain support for that need. Implement the mission operations plan.	Desired system
	Phase F Closeout	To implement the systems decommissioning/disposal plan developed in Phase E and perform analyses of the returned data and any returned samples.	Product closeout

Mission can be stopped at any of the red triangle

(NASA systems engineering Handbook)

Various points of view





Building an instrument requires several points of view

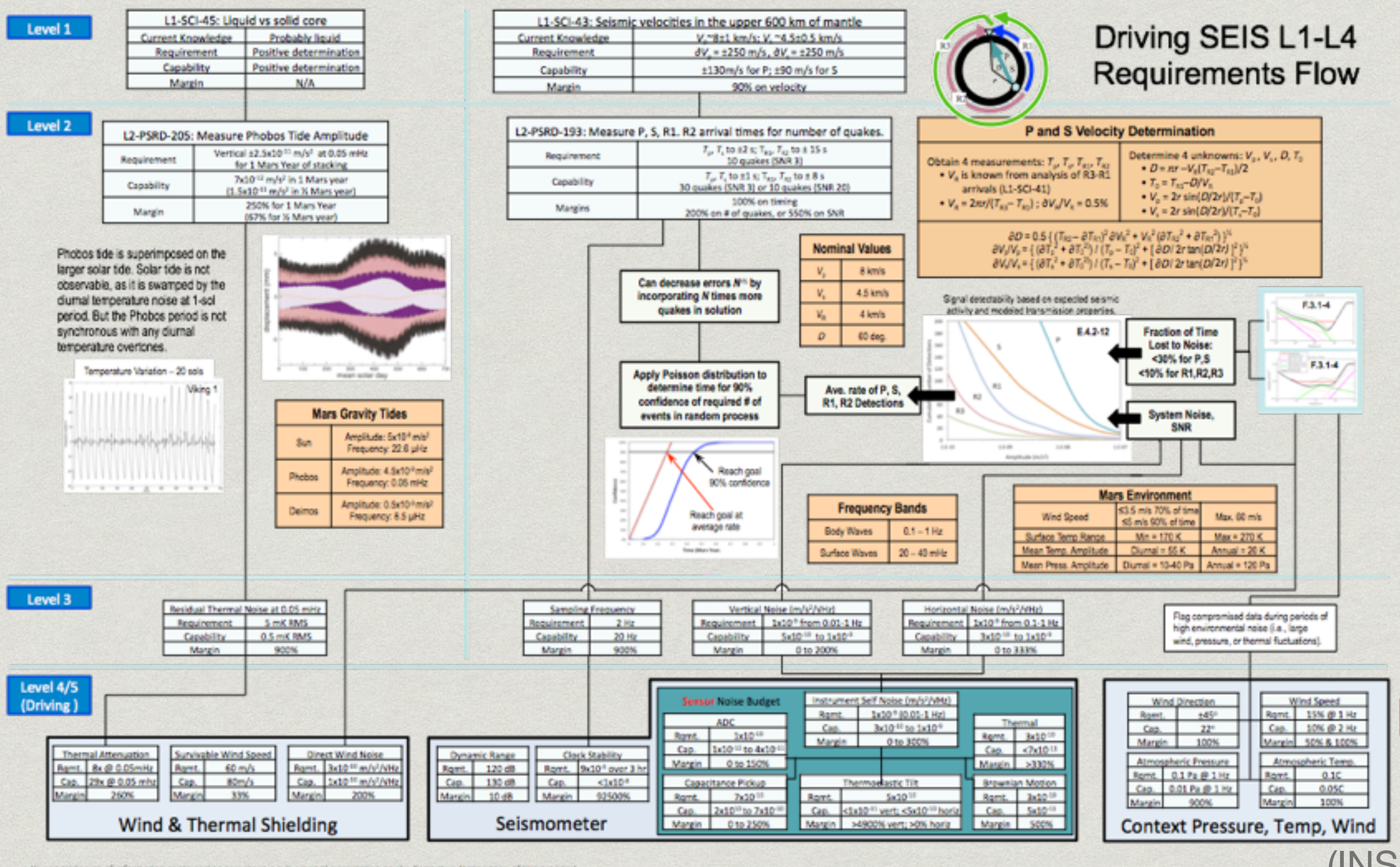
A small number of lessons learned (and it’s not the end of the story)

- Build strong requirements
- Build strong development plan with ample margins
- Pass early shock and vibe tests - integrate early subsystems
- Use space qualified parts early in the design (if possible)
- Plan early the validation and verification strategy
- Make an instrument that can be tested on Earth (as far as possible)
- It’s a lot of work : have a good team and keep the good team spirit in all circumstances

Build strong requirements

- Strong missions and instrument requirements are the key to a successful project
- It's not only « paperwork » or wasted time. A good or bad set of requirements will enable good communication with the team actually building the instrument or the mission. It drives the mission cost very early
- It must be understandable and verifiable by anyone not familiar with the science details : this is what *will* happen eventually
- Small is beautiful : a good requirement document is a document where you cannot delete something

A strong and robust science case is required



Mission

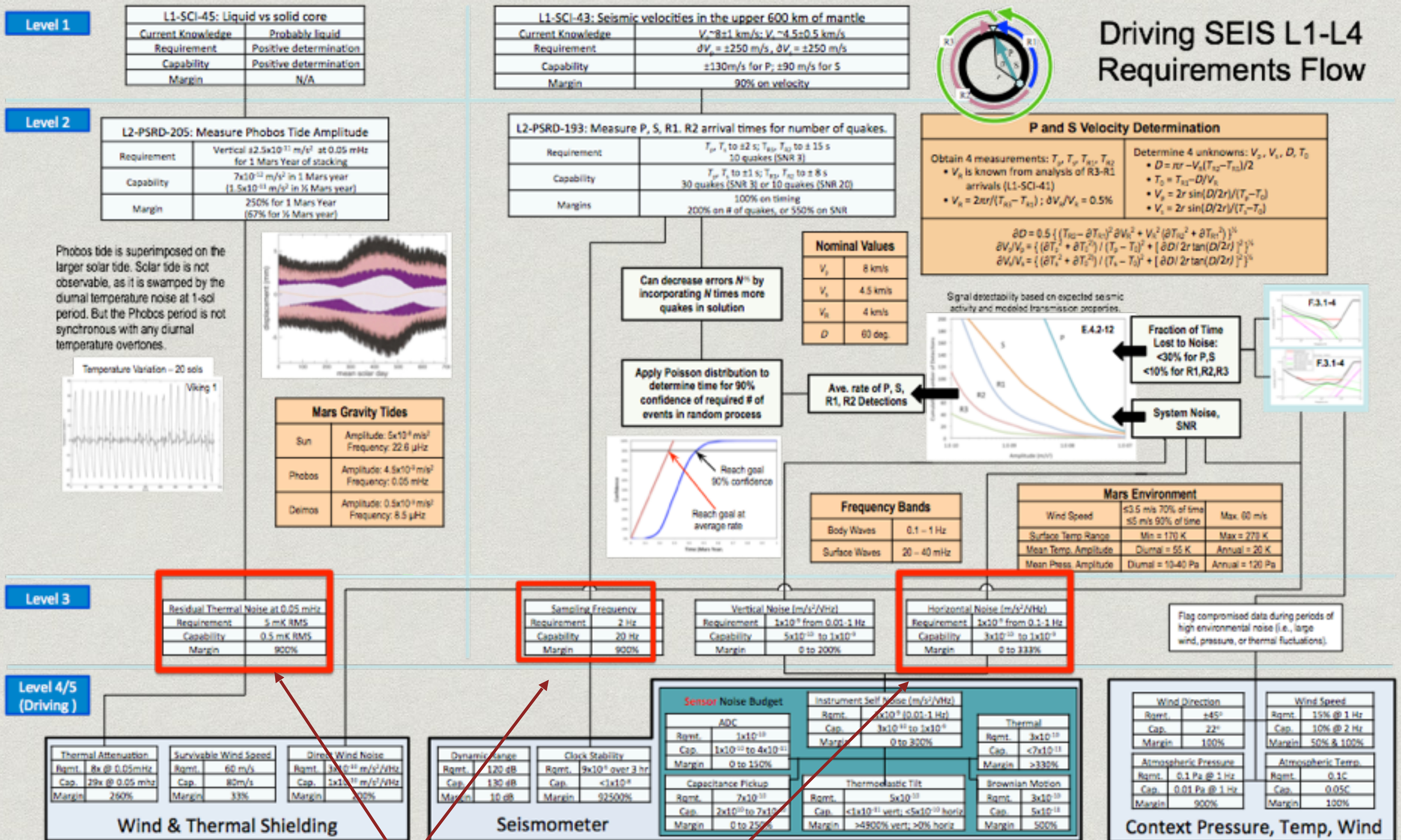
System

Payload

Instrument

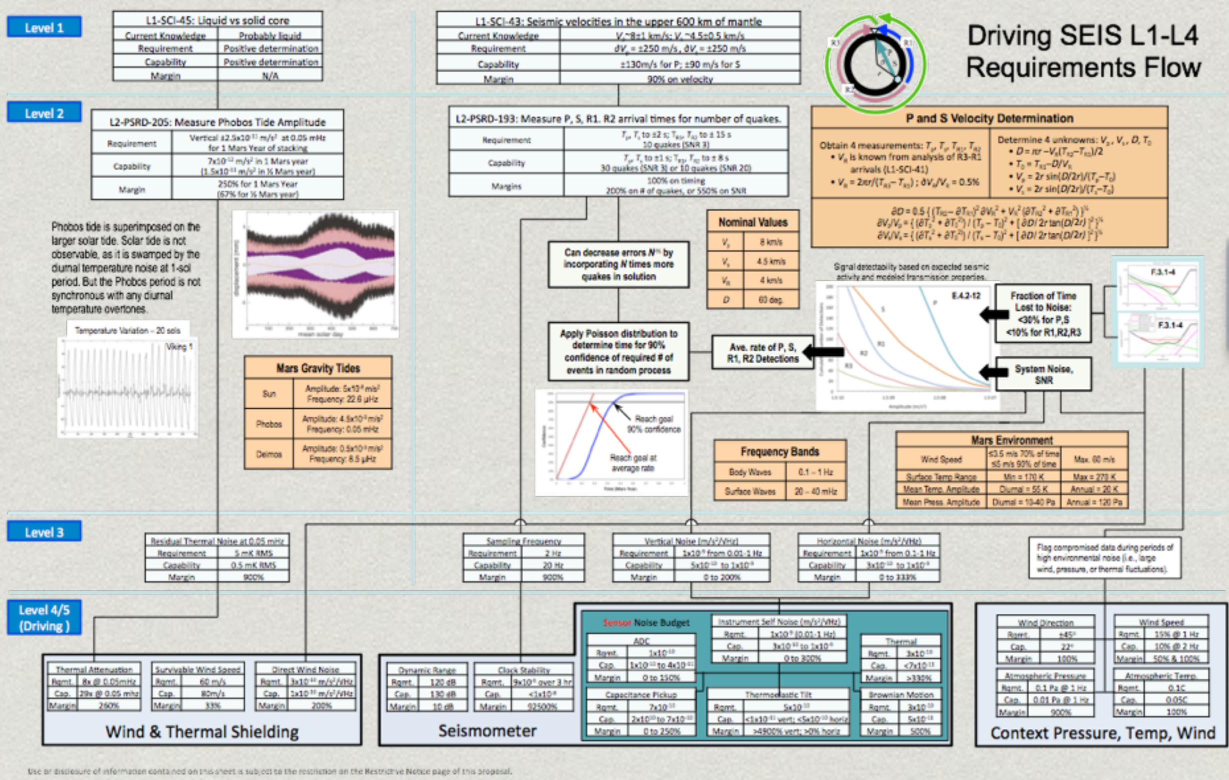
(INSIGHT TEAM)

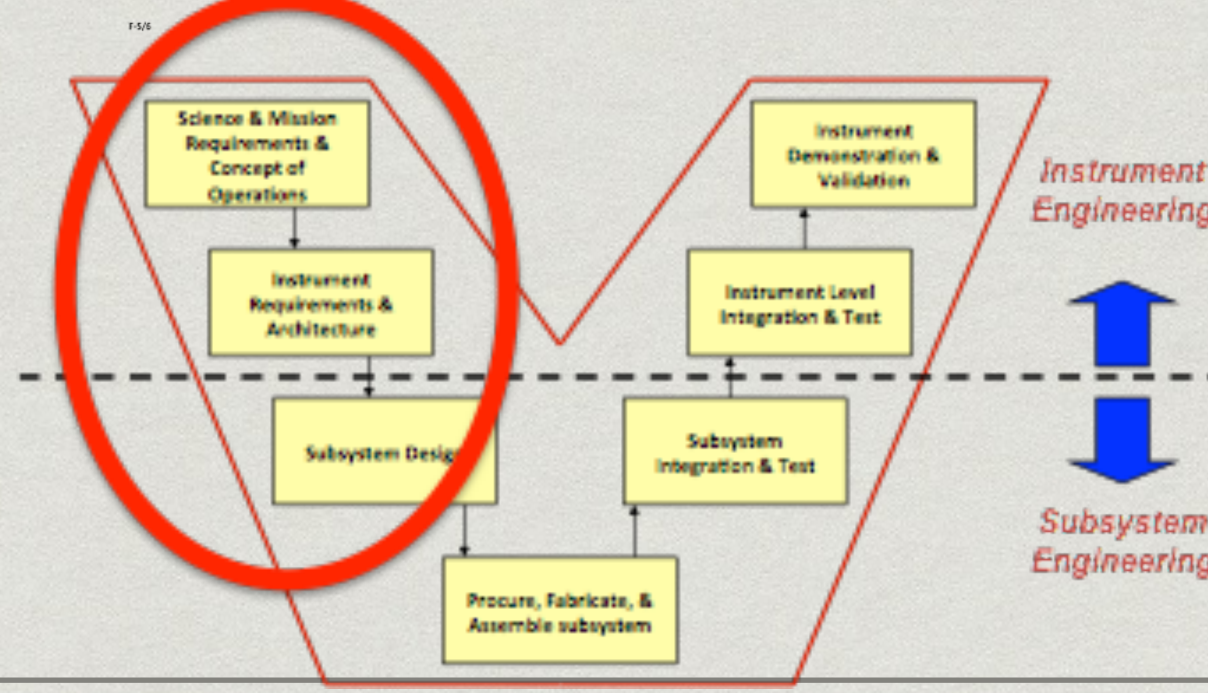
Because you have no assurance that everything will be fine …(*)



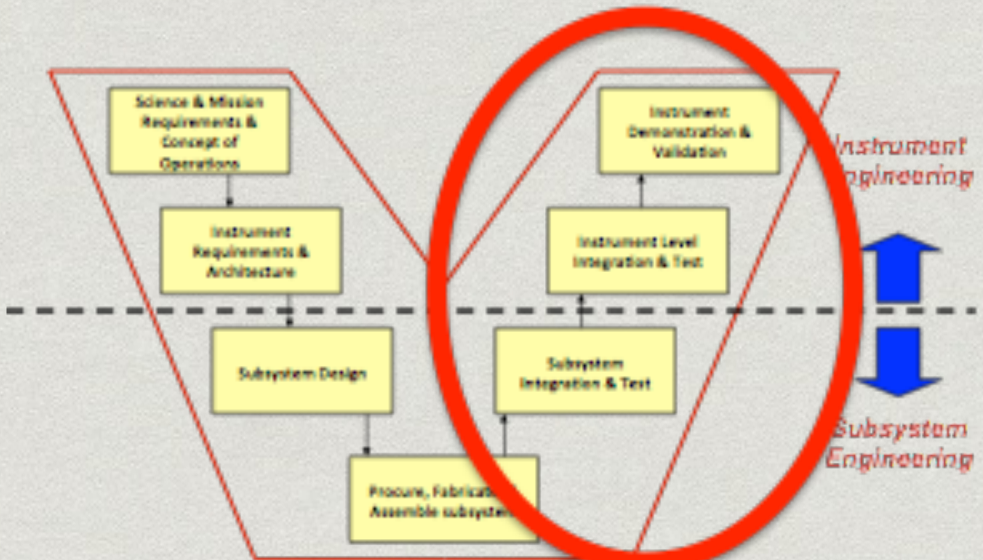
(*) ACTUALLY YOU CAN BE SURE THAT THINGS WILL GO WRONG

The performance flowdown drives the requirements

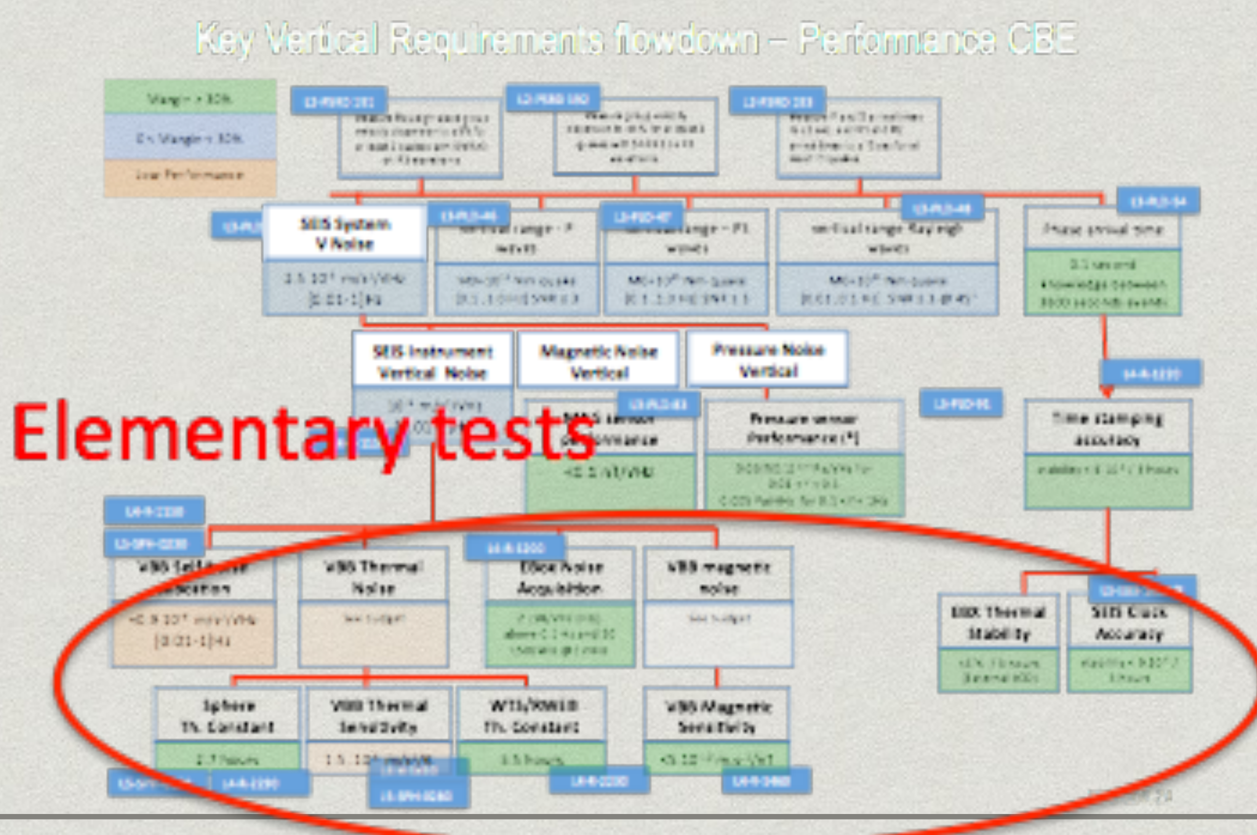


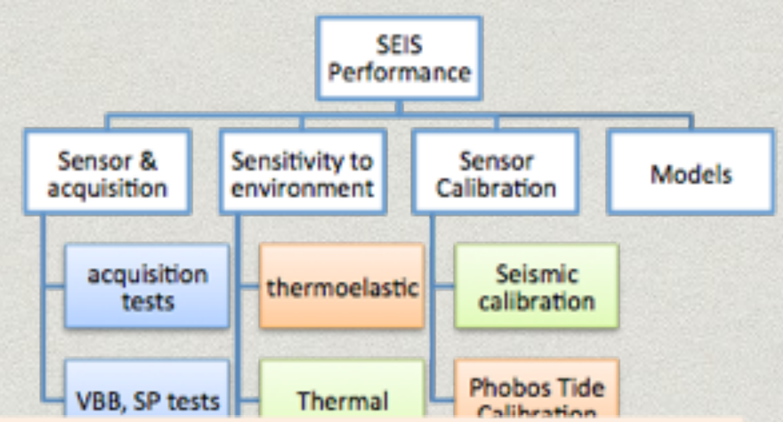


You need a good model for performance reconstruction



L1 Requirement	L2 Requirement	CSR Capability	CSR Margin	CDR Margin
L1-SCI-41 Determine the depth of the crust-mantle boundary to within ±10 km	L2-PSRD-191: Measure Rayleigh wave group velocity dispersion to ±5% for at least 2 quakes with SNR≥3 on R3 wavetrains.	13 quakes	550% (quakes)	≈350% (quakes)
L1-SCI-42 Detect velocity contrast ≥0.5 km/sec over depth interval ≥5 km within the crust, if it exists.	L2-PSRD-192: Measure group velocity dispersion to ±4% for at least 3 quakes with SNR≥3 on R3 wavetrains.	13 quakes	330% (quakes)	≈200% (quakes)
L1-SCI-43 Determine seismic velocities in the upper 600 km of the mantle to within ±0.25 km/sec.	L2-PSRD-193: Measure P and S arrival times to ±2 sec, and R1 and R2 arrival times to ±15 sec for at least 13 quakes.	30 quakes	130% (quakes)	≈50% (quakes)
L1-SCI-45 Positively distinguish between liquid and solid outer core*	L2-PSRD-205: Measure the Phobos tide amplitude to $\pm 2.5\times10^{-11} m/s^2$.	$\pm 7\times10^{-12}$ m/s^2	250%	Secondary to RISE Under assessment





The models are the "glue" to tie elementary performances to mission performance

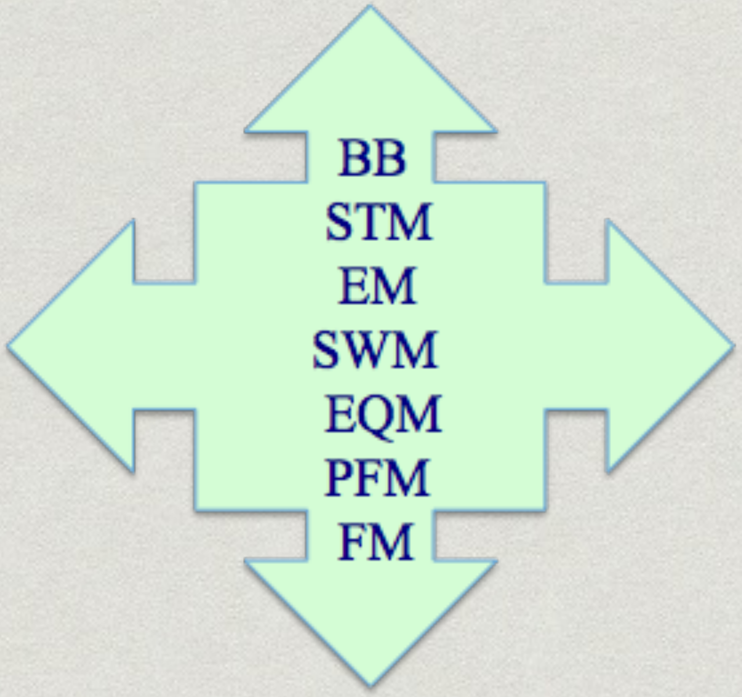
Development plan needs ample margins

Development plan must must

be setup carefully to match

mission objectives .....

and ressources



EQM can sometime be considered as schedule margin

Qualified parts

- Use qualified parts early in the design
- You cannot base your design on regular performance parts
- Space qualified parts are very limited in number and are low performance
- Qualification of new parts is lengthy and costly

13 pages (only)


ANALOG DEVICES
AEROSPACE PRODUCT LINE

Aug, 2011
Page 1 of 13

Space Qualified Parts List

Factory Contacts:

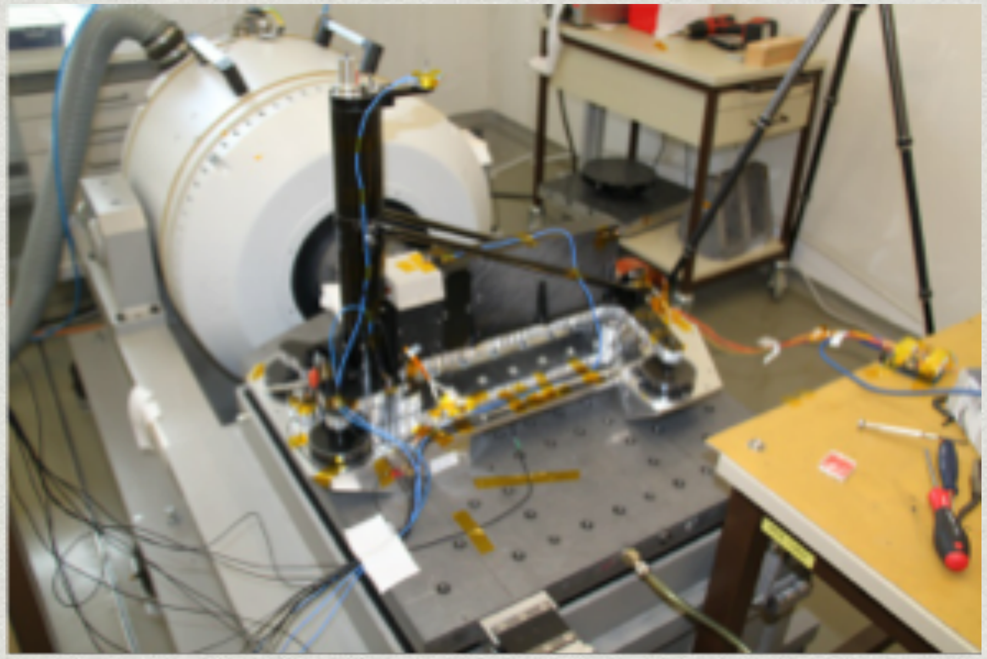
Tony Mercado (336) 605-4080, anthony.mercado@analog.com
Chris Leonard (336) 605-4385, chris.leonard@analog.com
Bob Barfield (336) 605-4063, bob.barfield@analog.com
FAX # (336) 605-4048

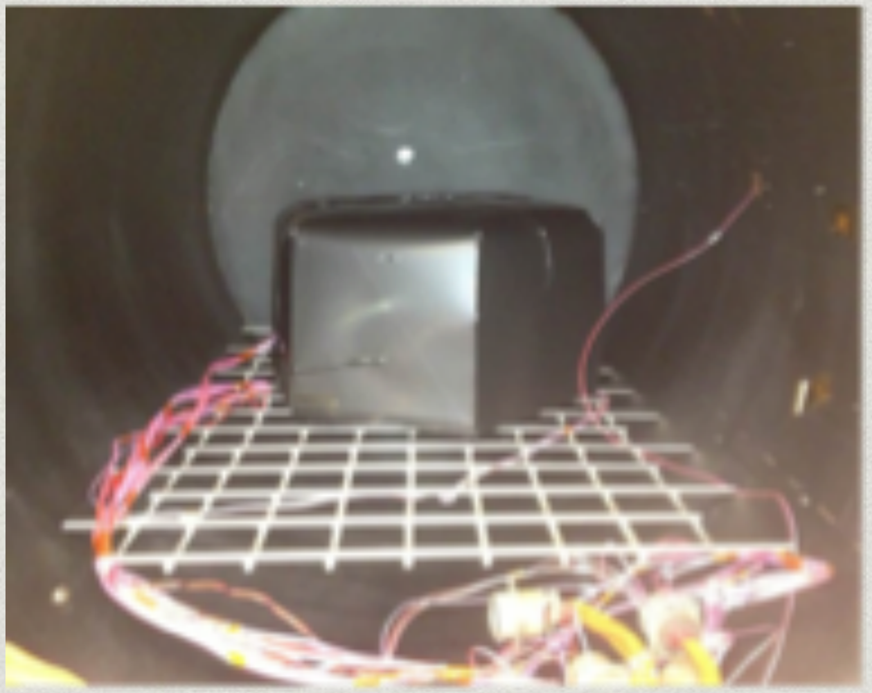
Address:

Analog Devices, Inc.
7910 Triad Center Drive
Greensboro, NC 27409
USA
http://www.analog.com/aerospace

Shock and vibe early

- Science instruments are often very fragile, and a mechanical weakness is likely to have severe impact on the design



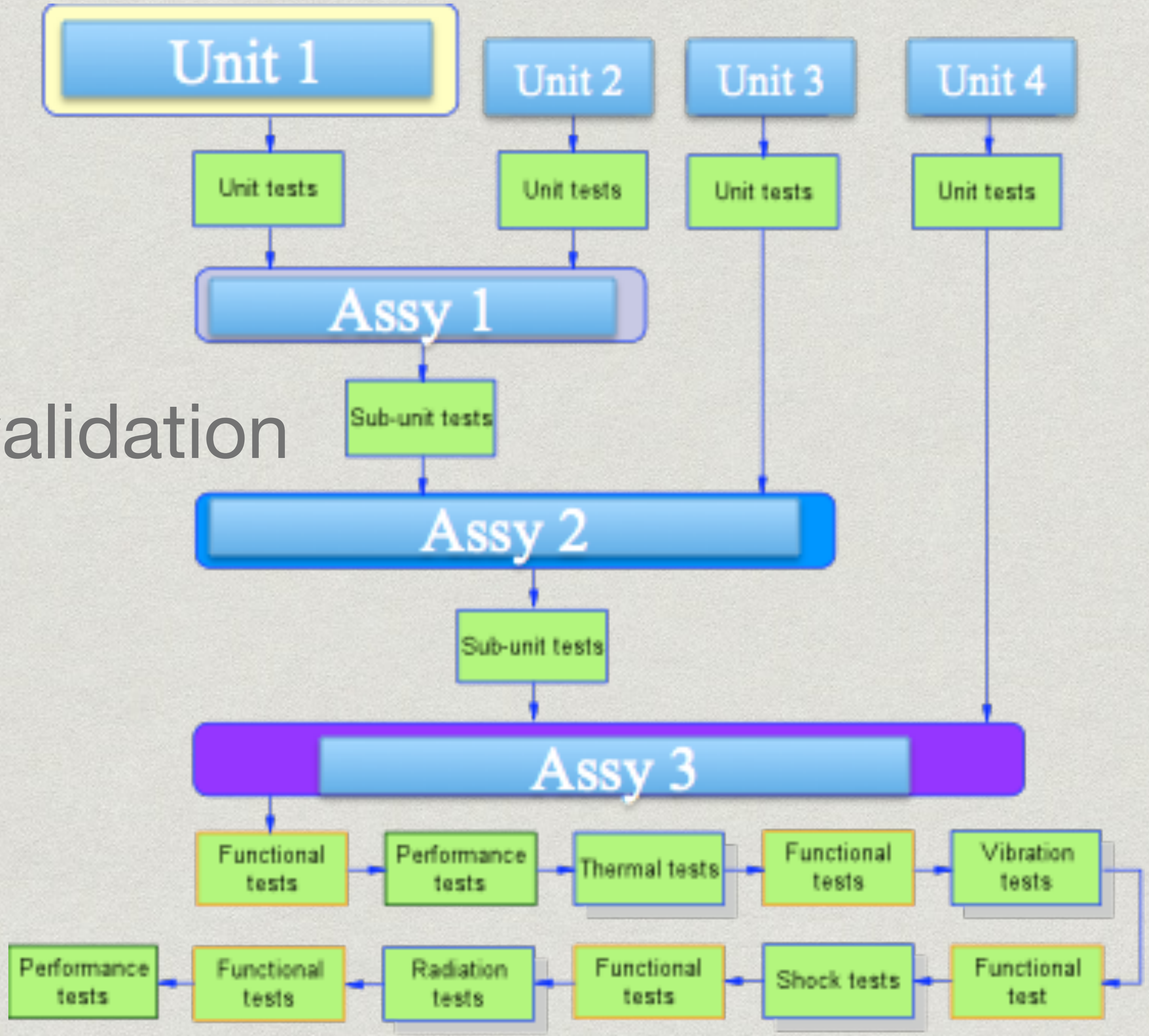


Integrate subsystems early

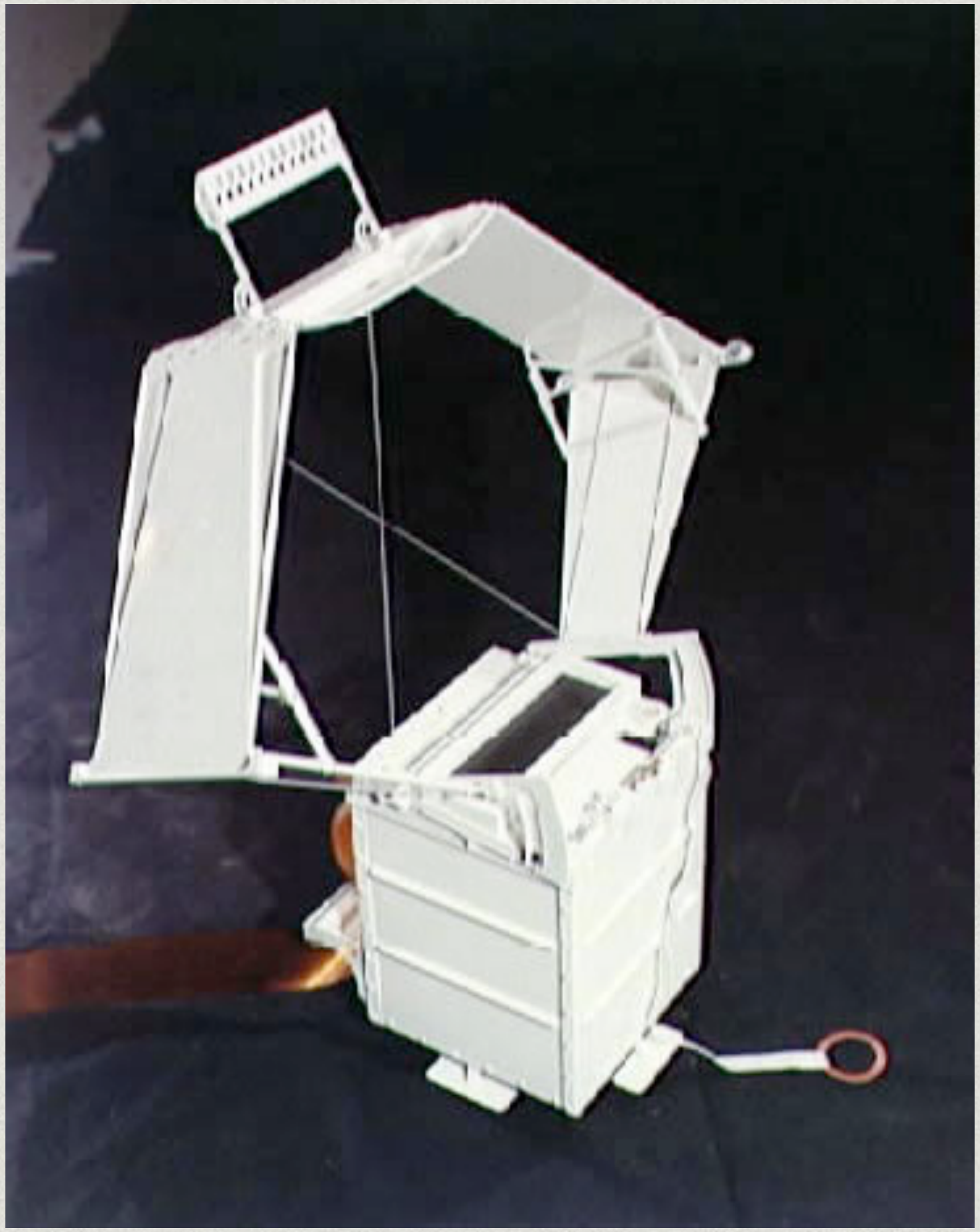
- Most of the time, science probes are the result of an international collaboration
- Example : ChemCam (Los Alamos Laboratories, IRAP) or SEIS (F, UK, D, CH, US)
- Issues in the interfaces can happen
- The sooner they are detected, the better

Plan early the validation process

- What is the VnV ?
  - Verification and validation
- Why plan early ?



Make an instrument that can be tested on Earth



Apollo 17 gravimeter could not operate on the Moon due to a flaw in the design

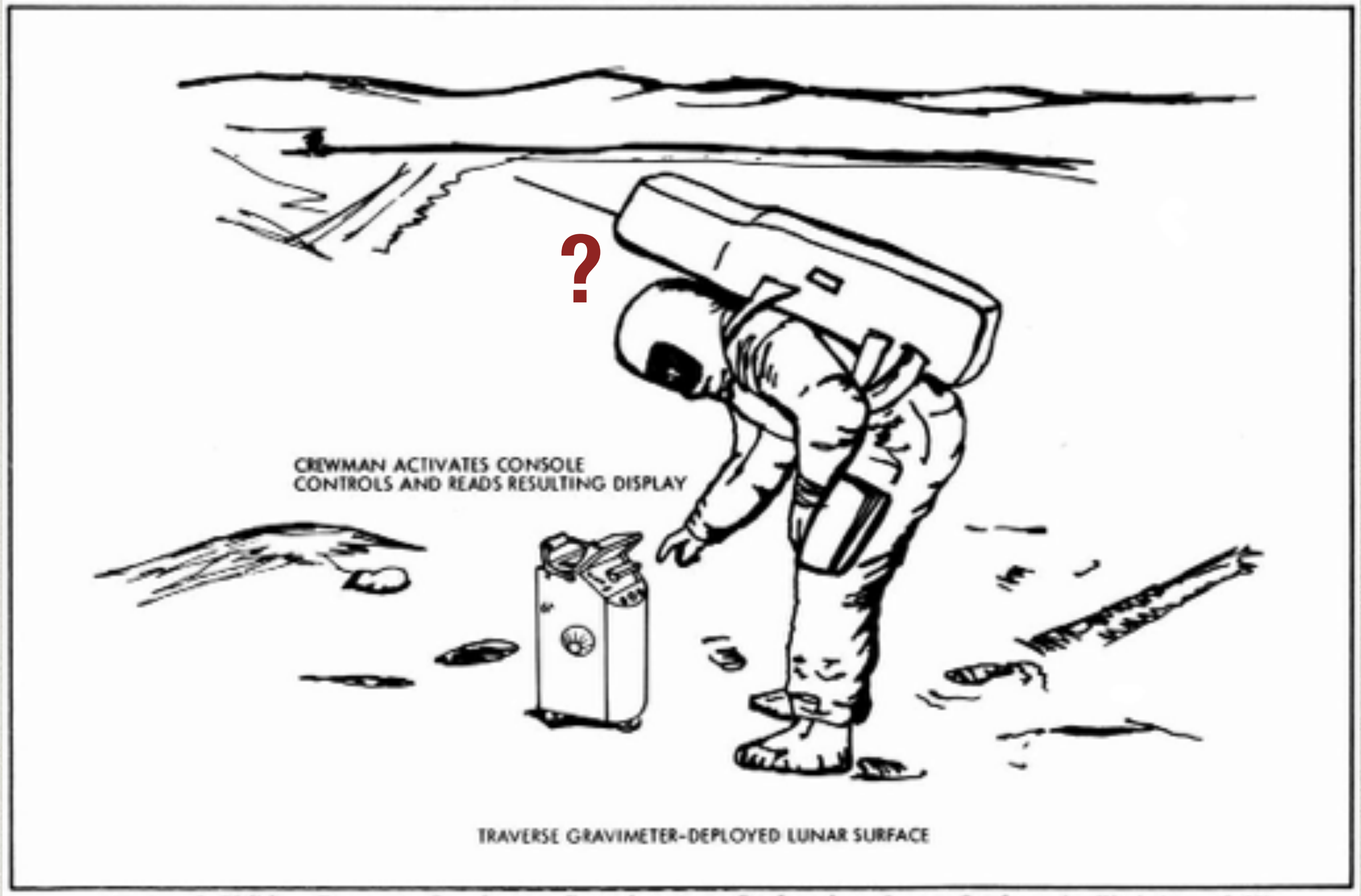
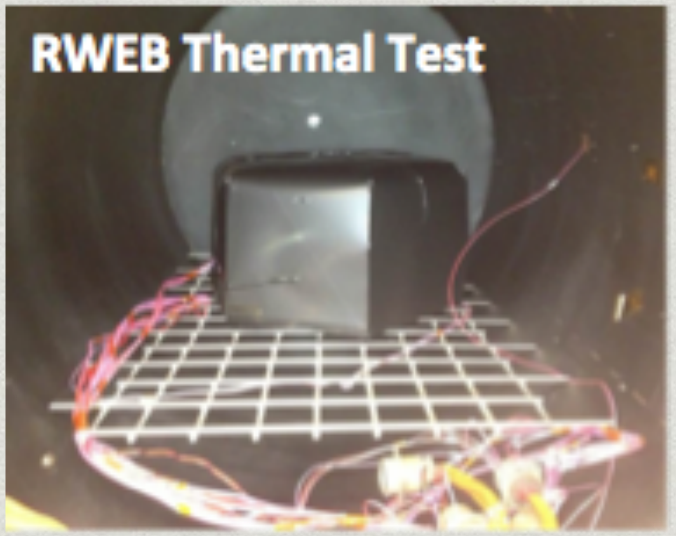
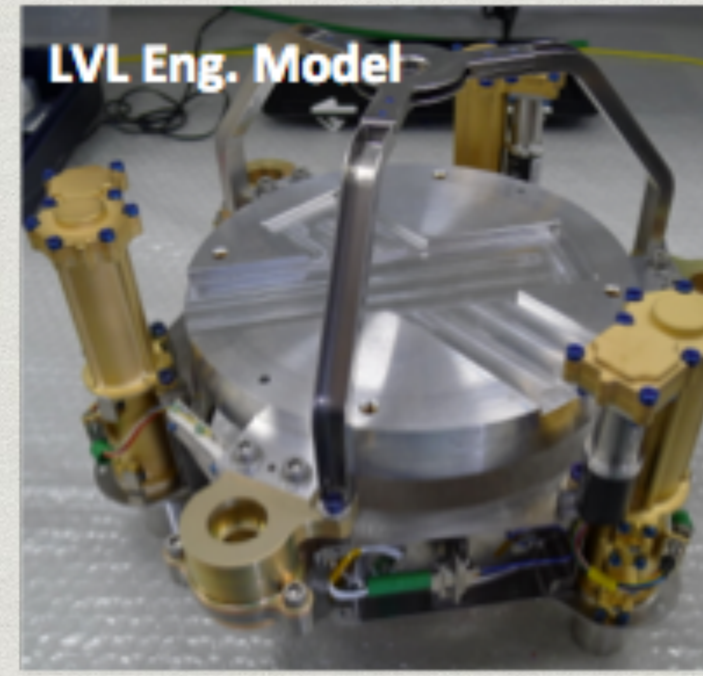
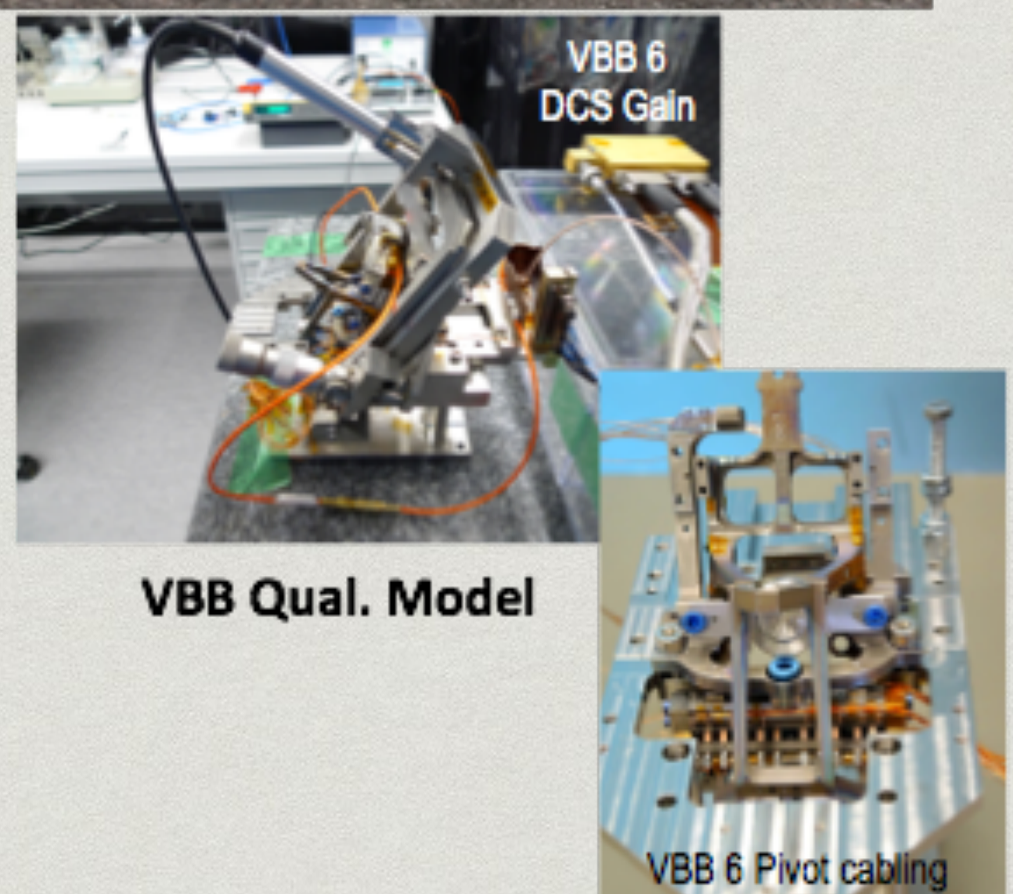


Figure 2-26(b). Traverse Gravimeter Experiment as Deployed on Lunar Surface in Vicinity of LM

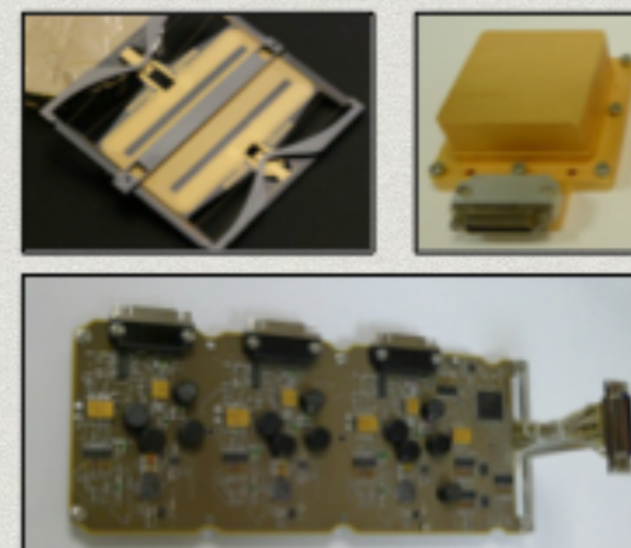
Tight Schedule for SEIS







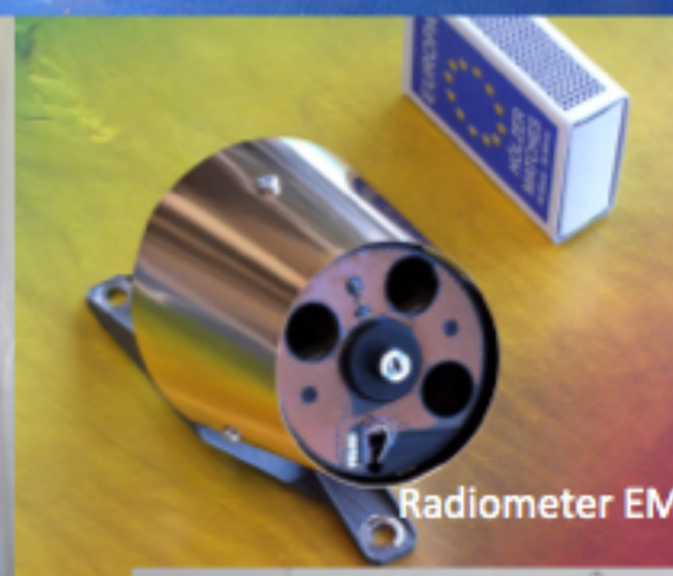
VBB Qual. Model

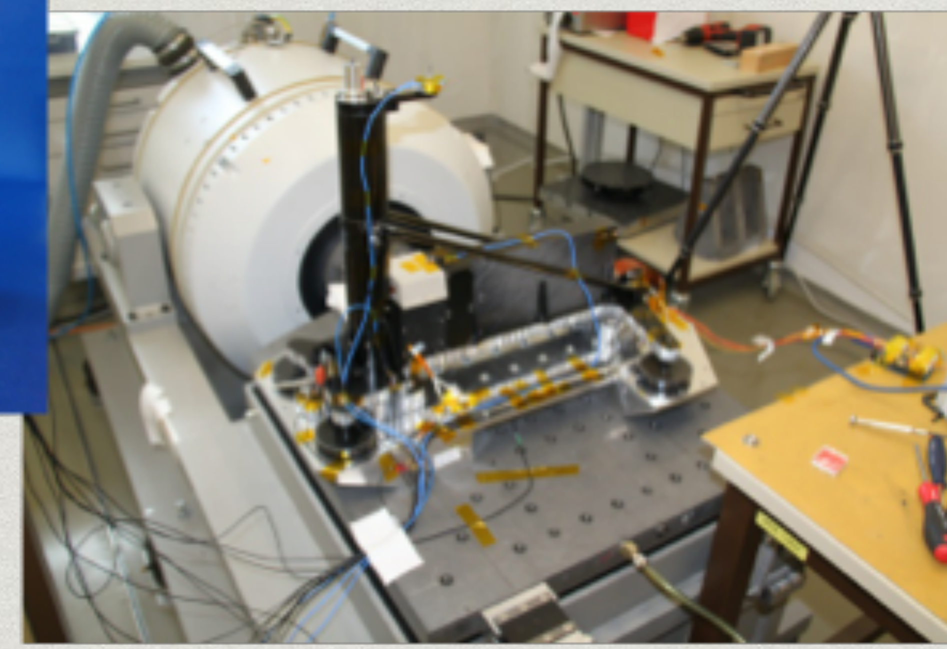


SP EM Sensor
and Electronics

Tight schedule also for the mole

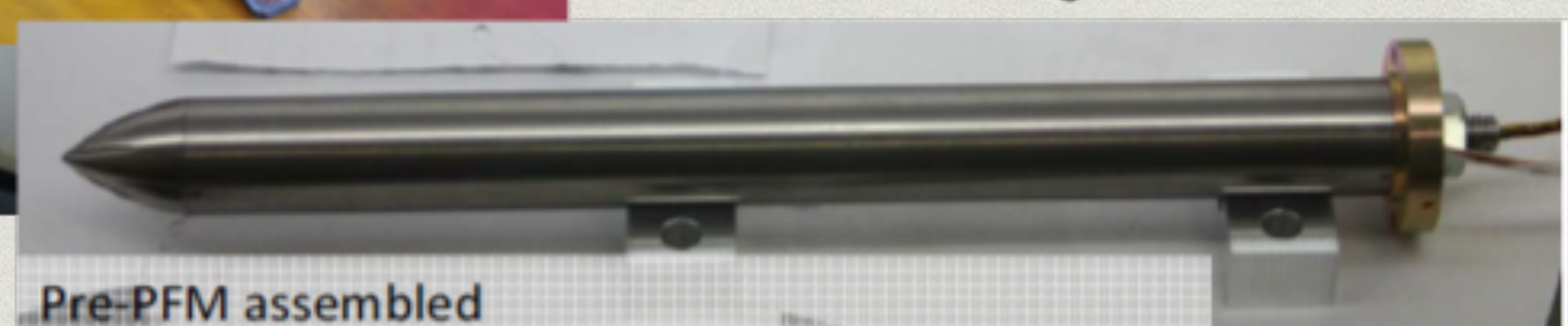
Geothermal Test Bed (GTB) @ JPL





Support Structure EM
in Vibration Testing

Mole Pre-Protoflight Model



Where are we today

- **Passed PDR and Confirmation Review**
- **In Development and Fabrication**
- **On Budget – Reserves Exceed NASA Guidelines**
- **On Schedule – Margins Exceed what Proposed**
- **Instrument & System Capabilities Exceed All Science Reqs**
- **May 2014: Critical Design Review**
- October 2014: System Integration Review
- January 2015: Deliver instruments to ATLO
- Participating Scientist Program
- ~dozen new scientists before launch
- November 2015: Confirm landing site
- December 2015: Ship to Vandenberg
- March 2016: Launch
- September 2016: Landing
- October 2018: End of primary mission

It's a lot of work : keep team spirit at all costs

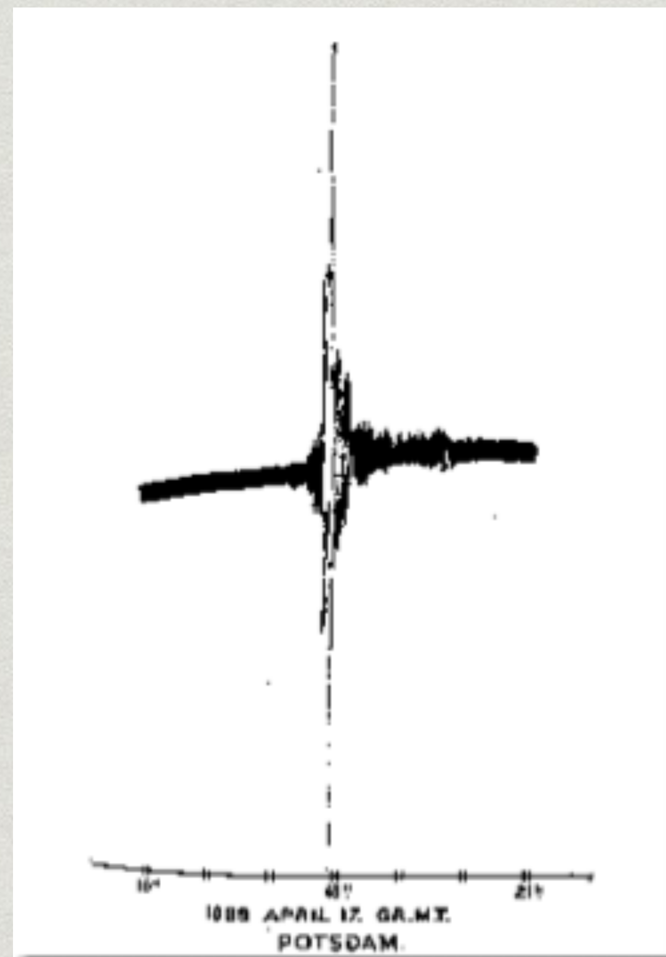
Pictures : L. Kerjean

And maybe …

132 AD

Chang Hêng, first seismoscope on Earth (132 AD)

1889 AD



Von Rebeur-Pacshwitz (Nature, 1889), first seismogram on Earth (M~5.8 in Japan recorded in Postdam)

2016 AD ?

First quake detected on Mars